

RICKETS



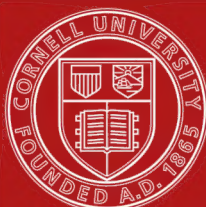
J. LAWSON DICK

M.D. Ed., F.R.C.S. Ed.

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Rickets: a study of economic conditions



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INFLUENZA

ESSAYS BY SEVERAL AUTHORS

**Edited by F. G. Crookshank, M.D. Lond.,
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Hospital, the French Hospital, etc.
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In this volume the editor has brought together a number of papers, especially written by himself and some nine or ten associates, that deal with various aspects—historical, epidemiological, bacteriological and clinical—of influenza. Amongst the writers are Dr. HAMER (London), Dr. DONALDSON (London), Dr. ABRAHAMS (London), Mr. WHALE (London), Mr. S. BOYD (London), and Dr. SMITH ELY JELLIFFE (New York), and Dr. DWIGHT LEWIS (Virginia). The volume will be of assistance and interest to all those who desire a broad and comprehensive view of the manifold and difficult problems raised by the attempt to elucidate the study of influenza and the allied epidemics and diseases.

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RICKETS

A Study of Economic Conditions and their Effects
on the Health of the Nation, in two parts
combined in one volume, freely
illustrated

BY

J. LAWSON DICK

M.D. Ed., F.R.C.S. Eng.

DEPUTY COMMISSIONER OF MEDICAL SERVICES, LONDON REGION,
MINISTRY OF PENSIONS; AUTHOR OF "DEFECTIVE HOUSING
AND THE GROWTH OF CHILDREN," ETC., ETC.

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To
N. W. L. D.

Printed in Great Britain.

PREFACE.

WHEN I was asked by the publishers, some eighteen months ago, to write a monograph on the subject of rickets, I undertook the task the more readily in that the subject had been one which had occupied my attention for many years.

One fact early impressed upon me was the comparatively limited world distribution of the disease, or in other words, that over large portions of the surface of the globe, notably in Africa, India, and the Far East generally, rickets was absent, or at all events was so slight and so occasional in its appearance that it was a factor of no importance in considering the health of these countries.

It was difficult to see why this should be, for experience taught that the life of the native of these uncivilised or semi-civilised regions was beset with hardships and dangers to which the young infant, in more sheltered conditions at home, was not exposed. The cult of the *untutored savage* does not now appeal to the imagination as it did during the eighteenth century, but nevertheless, there is no doubt that the child of such a race to-day escapes many of the diseases and morbid conditions to which children in civilised industrial communities in Europe are exceedingly prone. A notable example of such a disease is rickets.

At an early date I was further impressed with the inadequacy of the usual theories as to the ætiology of rickets. In Africa, India, and China, ignorance as regards the simplest dietetic principles is much more profound than in Europe, and gross errors in infant feeding are much more common. Under-feeding and the early administration of starchy foods are very frequent among rice-eating peoples. In many parts deaths from starvation and marasmus are common, and at recurring intervals, in India and China, there are devastating famines which involve the loss of many thousands of infants. If the prevailing theories as to the causation of the disease were true,

rickets should abound, whereas the extraordinary fact is, that under these circumstances rickets is conspicuously absent.

Prolonged lactation, as will be shown later, is exceedingly common among native races all over these countries, to an extent unknown in Europe, and with the breast feeding, at a very early date, starchy pap foods are given to the child, factors which are constantly blamed for the production of the disease in Europe.

Intestinal infections in the southern hemisphere and all over the Far East, of an acute nature, such as are seldom seen in England, are very prevalent, and chronic infections are frequent and stubborn and produce a high mortality.

Yet with all these adverse factors at work, rickets remains notably absent over the southern hemisphere and over Asia generally, or if present is slight and infrequent.

With children of European parentage, both in Africa and India, breast feeding is, as a rule, very inadequate. In South Africa, women of Dutch, and French, and English parentage, have now for many generations been resident in the country, and a strong and virile population has resulted. But even in this healthy climate, continued breast feeding is the exception, and failure of the supply of milk in healthy mothers at an early period is exceedingly common.

In India and China, where European stocks do not as a rule settle down to a permanent residence, suckling the child is still more difficult. As a result of this defect of feeding, and the associated absence of a proper dairy supply, many dangers to young infant life arise, but rickets is not one of them.

In Europe, rickets affects the majority of children to some degree, especially in the colder temperate zone. But there are notable differences, in various areas, as to the severity and the frequency of occurrence of the disease.

In the seventeenth century in England, rickets was an exceedingly formidable and severe affection, and its rapid diffusion caused widespread consternation throughout the land. Quite commonly it terminated fatally. At the present day the disease is more widely diffused in England throughout all classes, but the type has become considerably modified, and in itself is but seldom fatal.

To find cases of the severer type to-day one must proceed to the Continent of Europe. In no capital has the disease been

more rife or of a severer type for many years than in Vienna. During a residence of some months, spent at the Orthopædic Clinic in Vienna, some seven years before the beginning of the late war, not only was I impressed with the extreme prevalence of the disease, but the severe nature of the malady was borne in upon me. Cases of a type of severity, such as is described in the classic work of Glisson and in the writings of Mayow and other seventeenth century writers as occurring in England at that time, were quite common in Vienna long prior to the war.

From the point of view of the origin of disease the study of rickets is exceedingly important. It is an error of growth, and begins, as a rule, soon after birth. It is essentially a disease of the first two years of life, but no greater mistake could be made than to consider it only as a disease of infancy. The effects of rickets, contrary to what is generally supposed, are exceedingly prolonged. The disease tends towards recovery at an early period, but the results are well-marked throughout school life, and are very commonly evident in perverted and diseased growth in the adult. In a man of forty, by a study of the signs present in the skull, skeleton, and teeth, and by considering deviations which have occurred in the general growth, one can often make a shrewd guess as to the state of health and the environmental conditions during the first years of infancy.

Probably no single factor at the present time has a more potent influence than rickets on the standard of national health. It attacks the new-born infant at the time when it is released from a vegetative existence, in which its nutriment is elaborated and supplied through the maternal circulation, and its environment is the sheltered seclusion of the womb. The child at birth has rapidly to adapt itself to an enormously extended environment and has to carve out for itself, as it were, the course and line of growth which it will take.

To the agency of the rachitic state must be ascribed, in a large measure, the production of the defective class, the existence of which was so vividly brought before the nation in the late war. Statistics of the rate of incidence of births and deaths in the general population convey but little information as to the state of the public health. What is required is a detailed survey of the general health of the people, and of the degree of mental and physical vigour to which they attain in

all classes of the community. The partial observations which were made during the late war prove that enquiries on these lines are entirely at variance with the favourable results suggested of late years by mortality tables and birth rates.

A detailed study, extending over some twelve years, of the conditions prevailing in the north-east sector of London, the limits of which are defined later, has enabled me not only to furnish statistics of the incidence of the disease, but also to examine critically the factors which are concerned in its production. Through the courtesy of the London County Council, I have had extensive opportunities of making a special study of the school children in this area. This I have been able to amplify later by a study of infant growth at the welfare centres in the industrial areas of Hackney, which also come within this sector.

The social conditions of this part of London have, as will be shown, been very carefully and accurately worked out by Mr. Charles Booth, in his minute enquiries into economic conditions in London.

In considering the geographical distribution of rickets, in addition to relying on personal observation, I have culled information from many sources. Nothing is more tedious and conveys less to the mind than a bare enumeration of the areas in which a disease is found, and therefore, as far as possible, where the information lends itself to such treatment, it is arranged in the form of tables which can be readily apprehended.

To the Surgeon-General of the United States Public Health Service, Washington, and to Dr. W. H. Davis, Chief Statistician for Vital Statistics, Washington, I am indebted for much valuable help. From the members of the profession throughout America I have also received that friendly courtesy and readiness to help which my experience while travelling in the United States would have led me to anticipate.

From the colonies I have received much valuable information, and I am under a debt of obligation to Mr. A. M. Laughton, Government Statist for Victoria, for many facts regarding rickets in that State. Dr. T. Fletcher Telford, Medical Officer of Health for Christchurch, New Zealand, has taken the trouble to circularise and tabulate the answers from eighty-seven medical men in the Canterbury-Westland

district, and the results are all the more interesting in that they show an almost complete absence of the disease. I have to acknowledge much friendly help from Mr. C. E. Wallis, L.D.S., in my work on the teeth.

Lastly, I would like to record my indebtedness to the board members, and more especially to the specialists, attached to the London Region Headquarters of the Ministry of Pensions, who have brought to my notice many cases illustrating the subject in which it was known I was interested.

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PART I

THE GEOGRAPHICAL DISTRIBUTION, SIGNS AND SYMPTOMS OF RICKETS

CHAPTER I

INTRODUCTION

IN the study of disease there are two ways in which the subject may be approached, firstly, as it affects the individual, and secondly, as it affects the community of which the individual forms a part. In ordinary practice, there is a danger of considering morbid states simply as they affect patients and of forgetting the larger issue.

There is a national pathology as well as a clinical entity which can be summarised as a definite morbid state affecting the individual. This national tendency to disease is acted upon by numerous and diverse factors. Race, climate, economic conditions and environment, diet and customs, all produce wide variations.

In the enthusiasm which followed the discoveries of Pasteur, Lister and Koch, the study of the microbic environment of man led to a wide and wholesome broadening of the outlook on the factors which produce disease, and on the steps necessary for the purposes of prevention and cure.

Instead of the control of disease being simply a matter of treating symptoms by the individual practitioner as cases came under his observation, the medical officer of health took up the practice of preventive medicine with the greatest benefit to the community at large. Typhus and typhoid fever have been well nigh abolished over large areas, and that from great towns and cities, where the task might well have seemed impossible to the observers at the beginning of last century. Diphtheria has become a diminished scourge, and tuberculosis, up to the beginning of the great war, seemed to be lessening apace, while conditions such as malaria are now within the means of control.

The outlook of state medicine has, however, up to the present time been comparatively restricted. The results of state efforts on behalf of the public health have been estimated in terms of percentages of deaths, reckonings of the periods of the expectation of life, and the rate of incidence of zymotic disease, but morbid conditions as they affect the essential virility of the race have been largely unobserved till the advent of the great war. The rate of reproduction is no criterion for estimating national health, for under the worst conditions populations frequently increase with extraordinary rapidity, as indeed occurred during the period of unprecedented distress leading up to the industrial revolution in the beginning of last century. Notwithstanding the enormous benefits which have accrued from the practice of public health, it is doubtful if to-day the total incidence of disease has been greatly diminished within the last few centuries, and it may be questioned if the national health, as measured by the powers of resistance of the general population to disease and the capacity for work and healthy living, has much improved.

The defective state of the national health was brought in a very lively manner before the eyes of the nation in the late war. Reason will be shown later for believing that the results of the work of the Ministry of National Service, as detailed in their report for the year dating from November 1st, 1917, that is in the fourth year of the war, cannot be accepted as a true estimate of the state of the public health. But what the figures do reveal is the existence of an enormous amount of disease and of faulty and impaired development of the nation, which hitherto had been quite unsuspected.

In considering the factors which interfere with the efficiency of the nation, those which produce their effects on the infant and on the growing child must be given the first place.

A poison such as alcohol may in one sense be called a racial poison, but it probably exerts its influence on the adult only. By leading to poverty and incompetence in

the head of the family, it produces hardships which bear heavily on the young of the nation, and is, in this way, dysgenic, but it is open to serious question if the abuse of alcohol has any direct influence on the progeny. The probability is that alcoholism is part of a vicious circle, and that an inefficient population born and bred in slum surroundings is more likely to give way to excess than one more healthily placed. There is a universal and natural impulse in human nature to seek relief from adverse surroundings, whether it be in alcohol, as in the northern temperate zone, or in opium or *cannabis indica*, as in the East.

Lead is an example of an industrial poison which produces more far-reaching effects and tends to lead to abortion and still-birth. Fortunately, it is a poison which is more capable of control than most of the so-called racial poisons.

Certain conditions, however, bear directly on the infant and the young child, and tend not only to lead to a high mortality in the young, but also to produce a large number of defects in those who survive, and lead to a lowering of the standard of health in the general population. Such conditions are syphilis, tuberculosis, rickets, and the incidence of zymotic diseases, notably scarlatina, measles, and whooping cough.

Of all these, rickets is the commonest disease of children in our large towns, and at the present day it is probably the most serious factor interfering with the efficiency of the nation. Syphilis and tubercle have both a high mortality, but the rachitic state is seldom directly fatal, and yet, by its profound action on the young organism at the period of greatest growth, it has probably a more direct influence on the national standard of health than any other single factor. The housing of the nation at the present day is deplorable, and the breathing of vitiated air, the absence of ventilation, combined with the lack of the opportunity of exercise and the neglect of proper cleanliness, are all factors which bear heavily on the new-born infant. The want of sunshine is a deprivation of the first moment.

Rickets is the sum of the penalties which the young pay for the unnatural conditions under which they live. It is a disease of the first two years of life, beginning as a rule immediately after birth, and, as already noted, in enquiring into the origin of diseased conditions, no subject is of greater importance than the study of rickets. In response to abnormal environment the vital processes of growth are retarded, and wide changes result throughout the system producing alteration of structure, not only in the bony skeleton, but in most of the organs of the body, and notably in the nervous system.

It may be stated with conviction, that in the infant of two, the child of school age is already clearly adumbrated, and that the retardation of growth, and the deviations in development which are found in the adult of forty, are commonly the result of the evil influences which bear so heavily on the young infant in this the great formative period of its existence. It is not maintained that rickets is the only condition arising as a result of unhealthy environment. Tuberculosis and the incidence of zymotic diseases, as already noted, are also agents which have a profound influence on the national standard of health, but of all the factors bearing on the young infant, rickets is probably the most potent.

The climate of England naturally renders its inhabitants prone to the disease. There is much rain and for a long period of the year but little sunshine. The population tends to congregate in large manufacturing centres, and the towns are covered with a pall of smoke from factories and houses which still further limits the amount of available sunshine. The use of artificial light has enabled the day to encroach far into the night, and the habits of the people have become so changed that a new phase of the day's employment is only beginning when, under natural conditions, man would be retiring to rest. In Shakespeare's day, at the public theatres the performances usually began at two o'clock in the winter, and three o'clock in the summer, and lasted from two to three hours. Now, eight, eight-thirty, or even nine

o'clock is considered early enough to begin a long play. Falstaff himself, when he wished to express a life of royster-ing dissipation, could think of nothing more forcible than "we have heard the chimes at midnight," which would be but a mild sensation for the youth of to-day. Among the poor the children keep very late hours, so that the nights are shortened, and the child awakes late and misses an im-portant part of the day which, for a long period of the year, is already too short. Rickets is a malady which stunts the growth of the body and retards the development of the brain. It is dysgenic in so far as it interferes with the development of the female pelvis and adds to the danger of child-bearing.

The effects of the disease, widespread throughout the system and commencing at an early period in the history of the individual, lead not only to arrested development but to deviations along pathological lines which have far-reaching effects on growth, the powers of resistance to disease and the virility of the race. It predisposes to bronchitis and other catarrhal conditions in the young infant, and increases the mortality arising from acute infec-tions, such as measles and whooping cough.

The relationship between rickets and tuberculosis is of prime importance considering the enormous frequency of both diseases. It is generally supposed that there is an antagonism between the two diseases, an idea which has arisen from the fact that rickets is a disease of the first two years of life, when tuberculosis is not supposed to be common. More careful observation, however, has shown that tuberculosis appears at an earlier age than was formerly supposed. Thus, in a series of 500 consecutive cases of tuberculosis in children, examined at the Great Ormond Street Children's Hospital by Dr. Still, it was found that tubercle attained its maximum frequency in the second year of life.* One hundred and thirty cases, or twenty-five per cent., occurred during the second year. Pulmonary tuberculosis,

* "Common Disorders and Diseases of Childhood," by Geo. Fredk. Still, London, 1915.

it is true, is rare in early life. The chief sites for the tubercle bacillus to find a nidus in children are the lymphatic glands, the bones, and the joints. Invasion of the mesenteric glands and of the bronchial glands is frequent, and when pulmonary disease does occur in children, it is usually secondary to an extension from the bronchial glands. It is suggestive to note that the sites affected in rickets are very similar, notably the ends of the long bones and the lymphatic glands.

Pulmonary tuberculosis is very rare in early life, and it is probable that the lymphatic type of child produced by the rachitic state is more strongly resistant to tuberculous invasion of the lungs than the healthy individual would be if exposed to similar surroundings. The lymphatic glands act as a vital filter, which not only arrests the bacillus but actively attacks the germ when arrested. It is probable that the general hyperplasia which takes place throughout the whole lymphatic system in rickets is of the nature of an adaptive change, and may be a factor of importance in aiding the resistance to pulmonary tuberculosis. If this line of defence, the lymphatic system, breaks down in children, the disease is apt to become generalised and acute miliary tuberculosis results.

Rickets causes much ill-health and tends to produce the ineffective type of adult, deficient alike in physical stamina and in nervous energy and stability. Much of the failure of the man-power of the nation in the late war had its origin in this disease.

One of the surprising features of recruiting was the number of men who, without suffering from any organic disease, had yet to be placed in a low category because they entirely failed to come up to the very modest requirements of the army standard. Apart from those who were rejected as unfit for foreign service, many of the men sent to France broke down under the strain of war service and were sent home as cases of debility, disordered action of the heart, etc. Another type was the man who did his work fairly well in civil life and whose nervous system was able to

cope with the ordinary exigencies of a business life at home, but who broke down under the strain of war conditions. These were frequently sent home as cases of shell shock and neurasthenia. In many, the defects which were latent in the nervous system would never have developed in ordinary civil life. It can readily be understood that prolonged shell fire and the exposure to active service conditions in the trenches would test severely even the most robust, but in these subjects with defective nervous stability the mere placing the man in the army, without service abroad, was sufficient in many cases to lead to a breakdown.

A very large number of men who served during the war suffered from deafness and discharging ears. These men constitute a heavy drain on the country by coming on the pension list, and also from the fact that their economic value in the labour market is very small. In ear infections, as a rule, the disease has existed from early childhood. Not infrequently it dates back to an attack of scarlet fever or measles, but in the great majority the condition which predisposed to infection from various sources arose shortly after birth and was directly due to an unwholesome environment and the development of the rachitic state.

In large numbers of these men the catarrhal suppurative otitis media does not stand alone but is associated with defects typical of rickets, such as the high arched palate accompanied by irregular and decayed teeth, deflected septum of the nose, hypertrophic rhinitis, adenoids or a history of adenoids, with the typical heavy expression of the confirmed mouth breather.

These three classes of men, namely, those who tend to swell the ranks of men suffering from debility and disordered action of the heart, those who suffer from nervous breakdowns frequently classed as neurasthenia, and those who suffer from old-standing conditions of otorrhœa associated with the history or presence of adenoids, enlarged tonsils, etc., are to a large extent those whose growth and development have been delayed and thwarted from earliest childhood.

They have passed through a rachitic stage, and, while the disease is no longer active, the results have persisted so that these individuals constitute a heavy economic loss to the State ; they are weakly and ailing, inefficient in most walks of life, unable to rise out of the vicious environment which surrounds them, and are likely to perpetuate these same conditions in their children, owing to the fact that they are exposed to a like environment.

Disease and health are only relative terms, and in a very real sense it may be maintained that there is no distinction to be drawn between pathological and physiological processes. All so-called morbid states of the body are but the normal response of the tissues of the living body to meet altered conditions, and as such are strictly speaking physiological. To state that infantile mortality is only a statistical expression of bad conditions by which infant life is surrounded, is a trite saying often quoted, which is only half a truth. For conditions inimical to proper growth and development do not necessarily lead to fatal results, but may produce changes of an adaptive nature which fit the young organism to survive under abnormal conditions which could not support robust and healthy life.

There is an essential difference between morbid states in early childhood and old age. In the very young infant, apart perhaps from congenital syphilis, diseased conditions are developmental. Disturbance of growth occurs which may assume the form of a simple retardation, or may lead to more or less wide deviations from the normal standard. In the aged, diseases are no longer developmental, but are due to failure on the part of the eliminative organs. Rickets is a type of the disease found in infancy, gout is the type found in advancing years.

Diseased conditions may, in infancy and early childhood, be adaptive processes actually tending towards the preservation of the race in an environment wholly inimical to the production of a sound and healthy manhood and womanhood. Rickets is such an adaptive disease and is produced by an unhealthy environment acting on the young

infant at the most impressionable period of growth, that is, immediately after birth.

Up to that time, the infant has been screened from adverse conditions in the security of the womb by the intervention of the placenta, and how perfect that protection is will be shown later. But at birth, the child is immediately thrown on its own resources, as it were, and has to provide for a rapid growth of the body seemingly out of all proportion to the food intake. At no period in its life is the organism more dependent on a healthy environment, and among the poor and the working class of our large industrial centres, at no period are the surroundings of the child worse than during the first two years of life.

The fault is not in the feeding. The great majority of the mothers breast-feed their infants, and the great majority of these children develop rickets. The mothers of the industrial class feed well. The coal miners as a community, to take a definite example, even before the war did not restrict themselves as regards wholesome food. But the conditions of life otherwise, as regards housing and all the ordinary amenities of life were, and are, harmful in an extreme degree to the new-born infant. The mother is not exposed in the same degree to these harmful influences. True, she suffers from them, as the whole community does, but she leads a free and independent existence necessitating a certain amount of change in her surroundings. But the young infant, especially during the severe winter months, is likely to remain practically in one room day after day for weeks and months, and the unwholesome influences which operate on it during the day are still further concentrated on it at night.

Though this unhealthy environment, ending in the production of rickets may, in this country, be reproduced in good class homes and under the most varied conditions, it is essentially associated with the growth of great industries and large cities, and especially with the development of slum areas. Contrary to what is usually held, it will be shown that the disease is one of comparatively modern

times in England, having existed as a common disease among the people for probably not more than four hundred years. The reasons for coming to this conclusion will be explained fully in discussing the natural history of the disease.

During this period, a sparse population in England, forming a purely agricultural community, widely distributed over the country, has grown into an enormous industrial population mostly concentrated in large cities. The greater part of this growth has occurred since the end of the eighteenth century, and so rapid has been the increase that there has been no time to lay out a healthy plan of expansion. Nature has been faced with the enormous problem of how best to adapt this rapidly increasing population to these extraordinary changes in environment, and in the whole manner and mode of living of the people. From being a people dwelling in small communities, regulating their lives by the sun and spending the greater part of their day in the fields, they have developed into a people living in slum dwellings in densely crowded areas, spending their days in factories and workshops and prolonging their activities far into the night.

Rosy pictures of this agricultural period are often painted, portraying a life of measured toil and ease, when the people lived on dairy produce and food was plentiful. The reverse was the case. Life was a hard and strenuous struggle for the common people; the commonalty lived from hand to mouth, and the diet was monotonous, scanty and coarse.

Milk was universally interdicted for the use of children. Of the numerous books written for the use of midwives and nurses, all agree that cow's milk is poison to the child. Nor was this without good foundation in fact. Cleanliness in the handling of milk was not understood, and dysentery and diarrhoea were so generally fatal when it was given, that its use was universally and entirely avoided in the nursery. The difficulties and dangers of infant feeding in these early times were much greater than now. These matters will be gone into later in discussing economic factors in England

bearing on the disease. Yet with all these strenuous conditions and hardships, rickets, as will be seen later, was a disease unknown in England between three and four centuries ago, and it was only as the people were weaned from the land and were compelled to live in houses and great cities under highly artificial conditions, that the disease arose and spread over the land.

To adapt the population to these rapid economic changes, the means adopted by nature have been many, and the production of the rachitic state is one of the chief of these methods.

Malthus believed that one of the chief weapons employed by nature, was a high mortality as the increasing population kept pressing towards the limit of the means of subsistence. In 1798, was published his famous *Essay on Population*, in which it was maintained that while the population increased approximately in a geometrical ratio, the means of subsistence did so in an arithmetical ratio only. Thus the population was ever pressing towards the limit of the means of subsistence, and when it came perilously near, vice and misery stepped in as correctives. This was a soothing doctrine to the governing classes at the close of the eighteenth century, in that it tended to show that the terrible conditions which had arisen were the result of inexorable natural law. Malthus was a clergyman, sincere and estimable in his character, who was profoundly struck with the deplorable spectacle of many people starving and all workmen miserable in a population amounting to ten millions. But Malthus did not reckon with the power of adaptability of nature, and in place of the population diminishing, it was found that the greater the misery the more the population increased in numbers.

Broadly speaking, then, it is maintained that rickets is a disease of crowded slum areas, but, as will be shown, wherever conditions comparable to these are reproduced—and this is readily accomplished in such a climate as that of England, even in the homes of the wealthy and in the midst of country surroundings—the disease tends to arise.

The fact that it can be produced in such surroundings does not alter the fact, however, that rickets has grown up as the result of the industrial concentration of the population.

Now, in speaking of these conditions as associated with the development of the rachitic state, it will be well to define at once what is the nature of the industrial conditions referred to. It is not the effect of employment in the workshop or factory or warehouse on the parent, for rickets is not an inherited condition. Nor, in considering the cause of rickets, are we at all concerned with the effect of child labour or of the employment of women, whether married or unmarried. The employment of child labour will be referred to later, but it must be remembered that rickets is a disease which originates soon after birth, in the first few months of infancy, and that, though the results of work in the factory on the young organism were pernicious in the extreme, the influence on the rachitic state was a secondary one, on a disease already established and due to other causes. Wise legislation has fortunately removed most of the gross evils connected with the employment of women and children, and while nothing can justify the employment of the mother when this necessitates her giving up suckling her child, the probability is that her employment in healthy surroundings under ordinary labour conditions is no bar to a normal pregnancy and the rearing of a healthy child. Up to the seventeenth century, and later, every mother bore her active share in the support of the household, as part of her ordinary work, in looking after the children and the home.

Rickets originates during the first two years of life, and generally appears almost immediately after birth, though it may arise at any time, even as late as the period of adolescence in rare cases. The essential conditions associated with the development of industries which produce rickets are defective housing and overcrowding in slum areas, with all the attendant evils in the way of defective hygiene.

The food factor plays no part in the origin of the disease. No deficiency or defect of feeding will produce rickets when the child is exposed to bright sunshine and lives much

in the open. Over a large area of the globe's surface where such conditions prevail, rickets is for all practical purposes unknown. Errors in diet in the East and in the tropics generally, are more common and more gross than in Europe, and the mortality from intestinal infections is often high, but rickets does not result. On the other hand, the best of feeding will not protect the child when it is exposed to the conditions which produce the disease.

In discussing rickets, the geographical distribution of the disease is first dealt with. The study of the world distribution alone is sufficient to refute the food factor as a cause of rickets.

Subsequently, the signs, symptoms and pathology of the disease will be dealt with, and an effort will be made to trace, in the adult, the stigmata which have developed as a result of the aberration of growth which occurred in infancy. The connection is a very direct one.

During the last quarter of a century, exceptional opportunities have arisen for studying the reaction of large sections of the population to very varying conditions. In the South African War, nearly a quarter of a million of men were employed overseas under active service conditions. There were many essential differences between the conditions which prevailed in the late war and the Boer War. The army in South Africa was entirely a volunteer army and did not, therefore, draw on the physically unfit as the late European War did. The conditions of service were, on the whole, much easier and the climate in which the campaign was conducted was one of the finest in the world. There was nothing approximating the intense discomforts and physical stress of trench warfare and the strain of continuous and intense shell-fire, unless exception be made in the case of the siege of Ladysmith. The great failure in the Boer War was in the protection against typhoid fever, a disease which was reduced to a minimum in the late war. Malaria of a severe type was common in the South African War, and was not infrequently combined with a typhoid infection producing a high mortality.

But, apart from these infections, the strain on the general physique and the nervous system was much less than in the European War. Wounds in the South African War were mostly caused by rifle fire and did not become infected as wounds did in the late war, and recovery was generally unimpeded.

The second and happier opportunity of studying a large section of the population was afforded by the introduction of the systematic inspection of school children, which revealed many defects, notably impaired physique, myopia, enlargement of the tonsils and adenoids and all the morbid conditions associated with mouth breathing and defective teeth.

A third and more important opportunity was given by the development of infant welfare centres, when for the first time an opportunity was given for the systematic examination of young infants, and the origin and development of such conditions as rickets could be critically examined.

Lastly, and most important perhaps of all, in the late war an opportunity was given for a rough census of the health of the whole community. From the nature of things the results obtained could at best only be approximate, but the numbers dealt with were so enormous that a large element of error was eliminated and figures of the greatest value were obtained. Not only was the nation passed under a critical survey, but their reaction to the severe strain of modern active service conditions could be watched over a prolonged period. All these various sources of information have been freely drawn upon in working out the many problems of the disease.

No fact was more clearly demonstrated in the late war than that there existed a large number of developmental errors which, while not incapacitating the individual when employed in some subsidiary walk in civil life, yet unfitted him for even the more moderate degrees of active service.

For a proper understanding of rickets, a critical historical study of the disease is very essential, and a somewhat

wide excursion has, therefore, been made into the literature and history of the disease, which dates from the year 1650. A still more enduring and more important record is found in the study of the bones and teeth from the earliest times.

It is usual to state that civilisation and rickets run together. Such a statement requires careful examination, for the disease is entirely absent from all the early civilisations, and in ancient writings there is no description of the disease which can be accepted as showing that these writers were familiar with it. This is all the more striking in so far as rickets is a distinctive disease, very easily described, the signs and symptoms of which are not easily missed. The study of the causation has been placed at the end of this excursion into the natural history of rickets, for to apprehend the ætiology it is necessary to have before one the geographical and historical evidence as well as the clinical and pathological aspects of the disease.

CHAPTER II

THE GEOGRAPHICAL DISTRIBUTION OF RICKETS

General Distribution and Distribution in Great Britain and Ireland

IN the study of the development of a people, or of a nation, and of the diseases from which it suffers, few factors are of greater importance than the physical conditions which surround it. Certain basic features of the environment mark out, as it were, the route along which the nations shall travel, and very often determine the degree of their advance, and set a definite limit to its extent. The effect of climate and food and the amount and nature of the toil required for the production of the necessities of life are prime factors of the greatest importance in moulding the career of nations.

It is a common statement that rickets is a condition coeval with civilisation. This is certainly not true of the early civilisations of Babylonia, Egypt, India and China. Not only is there no evidence of the presence of rickets among these early peoples, but there is now much positive evidence to the contrary, and up to the present day rickets does not exist over these vast areas, or at least is so mild and so infrequent that it is practically of no importance. It is not that it is diminished in frequency or in severity, but for all practical purposes it is absent.

The earlier civilisations were cradled in kindly nurseries. They had several great features in common. They were all distributed along the same degree of latitude and they were bred at the deltas and mouths of great rivers. The climate was tropical or sub-tropical, and the food of these early nations grew on the banks of these great rivers, which each year carried down fresh alluvial deposits, and spared the

labourer the unremitting toil necessary in colder temperate climates. If the Tropic of Cancer be followed round a globe of the world, it will be found that in the narrow belt between this line and 32° north latitude, lie the delta of the Nile, and the mouths of the Euphrates and Tigris, and the outlets of the Ganges, and of the Yang-tse-Kiang. At the estuaries of these great rivers were fostered all the early civilisations. All these are factors of the greatest importance in considering the development of these peoples, whether mental, moral or physical.

The source of food supply differed from that of pre-historic man in, say, the Neolithic period, and of the men of later date, in that it was produced from the soil and not by the stern toil of the chase. Food was relatively abundant and was easily produced. Civilisation made rapid strides, but, like all rapid growths, tended to a speedy culmination followed by a rapid decay. Probably the tendency has been to estimate their degree of civilisation too highly. Their greatest achievements were the products of slave labour.

There are two factors to be considered, firstly, the relatively ample production of food and its easy distribution. The word relatively is used advisedly, for the diet, as it is indeed to-day, was exceedingly restricted in variety. The date and various grains in Egypt, and elsewhere rice and other grains were the staple articles of food. In the earlier stages of the Babylonian and Egyptian civilisations there was probably a sufficiency of food for all, but in their later development there is little doubt that enormous hardships and privations were the lot of the great mass of the people. The second factor to be considered is the tropical and sub-tropical climates which these early peoples enjoyed. It is to this factor that these early civilisations owe their immunity from rickets, which is essentially a disease of modern civilisation and of overcrowding in great industrial centres and of cold climates and grey skies. All these are conditions depressing to the adult, but their full force is brought to bear on the young infant born in such surroundings, and it is little wonder that, with an environment so unnatural, the whole

growth of the child is often perverted and tends to progress along channels deviating widely from the normal. In Egypt, India or China, where infants are brought up in the open air and where they are bathed in daily sunshine from their birth onwards, no errors in food will produce the disease. In these countries and in the tropics generally, infant mortality is high. Intestinal toxæmias are exceedingly prevalent, and when they do not cause early death are apt to be very chronic and difficult to treat.

Prolonged suckling for two and three years, the nursing of the child while the mother is again pregnant, mixed feeding and the addition of starchy foods to the diet from a very early date, are exceedingly common errors in diet in these countries, but they do not result in rickets.

In tropical lands the people live mainly upon cooked cultivated vegetable foods. But little meat is used, not from choice but from lack of opportunity. The protein element in such a diet is small in amount, and this has a markedly deteriorating effect on their whole development.

The Japanese, it is true, who are largely dependent upon rice food, are a virile race, but they mature quickly and they have not the staying power of Europeans. They age rapidly and sixty years is considered a great and venerable age, whereas in England a man at this age is often in the enjoyment of full vigour.

Rickets, to-day, has a very striking geographical distribution. It is mainly a disease of the northern hemisphere, and placing the limits fairly widely, may be said to occur in Europe and North America between the latitudes 40° and 60° north.

In the southern hemisphere there are but few land masses in the corresponding zone between 40° and 60° south latitude. The 40° south latitude runs between Australia and Tasmania, so that Tasmania is within this zone. It runs through the southern portion of North Island, New Zealand, about the latitude of the town of Wellington, so that the whole of South Island is included, and it traverses the lower part of South America, so that the

whole of Patagonia is also comprised within the zone. It is a remarkable and noteworthy fact that outside this northern zone, in the rest of the northern hemisphere and in the whole of the southern hemisphere, including this corresponding zone, the disease is almost negligible and ceases to be an important factor affecting the health of the people. One exception will be noted in certain parts of Australia, but even here the condition is only incipient and is much less frequent and of a much milder type than in Europe and North America. Its importance in Australia at the present time is potential rather than actual.

In Europe the lower limit 40° north latitude is somewhat too far south. It would be more accurate to make the line 42° north, passing through the middle portion of Italy about the level of Rome and cutting off the upper fourth of Spain down to about the northern limit of Portugal. Roughly speaking, in Europe this zone, showing prevalence of the disease, reaches from the middle of Italy to the north of Scotland.

This belt is characterised by several distinctive features. Firstly, it embraces the most densely populated portion of the surface of the globe. Only two other portions of the globe's surface compare with it in this respect—India and China. Secondly, it is incomparably the wealthiest area on the surface of the globe and contains the great industries of the world. It has the advantages as well as the disadvantages of its industrial pre-eminence. The nations comprised within these areas are not solely dependent on the produce of the soil for their individual support. Since it is the great industrial region, the means of transport both by sea and land are highly organised, and the means of distribution are excellent. The distribution of wealth, though unequal, is yet vastly superior to what it is under more primitive conditions in the Far East. The failure of cereals in a portion of the United States of America, or in Canada or even in Russia, may cause financial loss and economic distress, but it would not be likely to produce any great deficiency in the actual necessities of life

in the area involved. The deficiency could be readily supplied from the outside. In India, on the other hand, failure of the rice crop over a wide area means disaster. Famine and deaths from starvation on a colossal scale—even under present conditions—are common.

At no time in the history of the world had there been a more equable distribution of food than there was in Europe up to the time of the great war. Meat and fish were, and are now, within reach of the common people, who up to two or three centuries ago rarely ate beef or mutton and were largely dependent on pork for the animal portion of their diet. Dairy farming has extended enormously. Fruits, coffee, tea and sugar are imported from other parts of the world, and from being luxuries are considered among the necessities of even the very poor. The use of the potato throughout the United Kingdom is universal, even with the poorest, and is probably the essential factor in largely banishing the disease scurvy from England. Malnutrition of varying degrees is common, but extreme distress from want of food is uncommon, and a death from starvation causes an agitation in the papers throughout the country. The disadvantages appertaining to the industrial areas will be dealt with in speaking of the conditions of life in the crowded populations of our great cities.

These disadvantages are notably accentuated by the third great feature which characterises this zone—that is, climate. This belt is entirely included in the temperate zone, the latitude from 40° N. to 45° N. belonging to the warmer temperate zone, while by far the greater portion, from 45° N. to 58° N. belongs to the colder temperate zone. The mean isothermal lines running through it vary from 30° Fahr. in the north to 80° Fahr. in the southern limit. In place of a rainy season rain falls at all times; there is much cloud shutting off sunlight, the winters are long and cold and wet, and the industries themselves affect the atmosphere of the large towns so as further to shut off the sun's rays.

The fourth characteristic of this zone is, that in the main it comprises the region of deciduous trees, and it is the great

grain growing belt for wheat, oats and rye. All these are factors of prime importance in considering the incidence and the ætiology of the disease.

Rickets is most prevalent in Great Britain, France, Belgium, Germany, European Russia, Austria, Hungary, and the United States of America. Countries in higher and lower latitudes are much less subject to the disease. In Greenland and the Farøe Islands and Iceland it rarely occurs. Hirsch notes that Finsen, in five years' practice in Iceland, only saw forty-two cases, and these of a mild type, while in the Scandinavian kingdoms (Norway and Denmark) it has a subordinate place in the statistics of sickness relating to the earliest years of life.* Southern Italy and the southern provinces of Spain and Greece enjoy a notable immunity. In Turkey rickets is usually thought to be rare, but some recent observations of Marfan would seem to show that this opinion, at all events for Constantinople, requires revision. In 1907, while visiting the hospital Hamidié reserved for children, Prof. Marfan was surprised to find a large number of severe cases of rickets in the wards, so severe indeed, that many of them required surgical interference for the correction of the deformities produced. Further enquiry outside the hospital elicited the information that rickets, often of a severe type, was commonly seen in Constantinople, nor was there any immunity of race—Turks, Greeks, Armenians, and Jews suffering alike.† When the conditions of life in this city of many nations is considered, it is little wonder that rickets is a factor affecting the health of young infants. Constantinople is beautifully situated on a promontory, with the Sea of Marmora and the Bosphorus on the south and east and the Golden Horn on the north. The climate is healthy but relaxing. It is damp and liable to great and sudden changes of temperature. Sanitation is still very defective. In 1900 the population was estimated at 1,125,000. The

* "Handbook of Historical and Geographical Pathology," by Dr. August Hirsch, Professor of Medicine in the University of Berlin. Pub. London. The New Sydenham Society, 1886. Vol. III, p. 733.

† "Traité de Médecine et de Thérapeutique." Brouardel et Gilbert. "XXXIX Maladies des Os, par Marfan." Paris, 1912.

streets are extremely narrow, dark, dirty and ill-paved, and so crowded and tortuous that hardly any two of them run for any length parallel to each other, the whole seeming one vast and incomprehensible labyrinth of filthy lanes. The houses are low and ill-built. It is but another instance of how a situation, in many ways ideal, can be spoiled by an utter lack of intelligence in town planning and carelessness in the application of the principles of every-day hygiene.

Distribution in Great Britain and Ireland.

In 1888, a committee appointed by the British Medical Association made a special investigation into the geographical distribution of rickets, acute and subacute rheumatism, chorea, cancer, and urinary calculus.* The report of the committee is of great value. The disease is common in towns and thickly populated districts, and is especially common where industrial pursuits are carried on. It is less common in rural districts. In England and Wales there are five great areas where the disease is very prevalent, and these areas correspond with five great industrial centres. These are: (1) the great northern coalfields of Durham lying between the rivers Tyne and Tees; (2) the coalfields of Lancashire and Yorkshire, including the great industrial towns of Lancashire; (3) the coalfields of the "black country," in the vicinity of Birmingham and Wolverhampton; (4) the coalfields of South Wales with Bristol and Clifton on the other side of the Severn and Bristol Channel; (5) the metropolitan area with its surrounding suburbs. (See Fig. 1, p. 23.)

The first includes the great towns of the river Tyne and the river Tees, and the seaport towns on the coast of Durham between these rivers which belong to the northern coalfield. The area in which the disease is prevalent does not extend far into the coalfield, Durham itself being comparatively

* "Geographical Distribution of Rickets, Acute and Subacute Rheumatism, Chorea, Cancer and Urinary Calculus in the British Islands." Reports of the Collective Investigation Committee of the British Medical Association, prepared by Isambard Owen, M.D., F.R.C.P., Secretary to the Committee. *British Medical Journal*, January, 1889.

free from rickets. Over a great area, including the greater part of Northumberland, the northern parts of Cumberland and Westmoreland, and the North and nearly all the East Riding of Yorkshire, the disease is not common.

The second area of great prevalence, and by far the largest, is found in a broad zone which extends from Lancaster on the west coast to Hull, Beverley, and Goole, on the east coast. This zone extends downwards on the west coast as far as the great industrial towns on the Mersey, and from thence the area dips downwards into the centre of England. It comprises the great coalfields of Lancashire and Yorkshire, and extends downwards into Cheshire, Staffordshire, Derbyshire and Nottinghamshire. It includes Liverpool, Birkenhead, Manchester, Preston, Leeds, Bradford, Halifax, Huddersfield, Sheffield, Derby and Nottingham. An island in the centre marks the Peak of Derbyshire, which is comparatively free from rickets. On its southern boundary this zone runs into the third great area where the disease is prevalent, and includes the great industrial towns in the vicinity of Birmingham and Wolverhampton. The fourth area of prevalence is found on either side of the Bristol Channel. In South Wales this comprises the great Welsh coalfields with Cardiff, Newport and Swansea as seaports, and also the populous industrial valleys of Glamorgan and Monmouth. On the other side of the Channel are Bristol and Clifton, in both of which rickets is very common, as it also is in Bath. From this, extending south towards the south coast and west into Cornwall, rickets is much more common than is usual in rural districts.

The report of the Collective Investigation Committee, already referred to, points out that in only eleven towns of 30,000 inhabitants and upwards is the disease scarce. These are Carlisle, York, Darlington, Scarborough, St. Helen's, Southport, Coventry, Buxton, Llanelly, Cheltenham, and Southampton. Among towns of moderate size the disease is still very prevalent, and it is not till small market towns with four to five thousand souls are reached that the disease again becomes rarer. The fifth great area where the disease

is prevalent comprises London and its outlying suburbs, In the slum areas in the East End of London, as will be found later, rickets is exceedingly common, 80 per cent. of children being rickety in the north-eastern sector of the metropolitan area.

In the London area, the wealthy residential suburbs of Mayfair and Belgravia are comparatively free from rickets. In South Kensington, Hyde Park, Bayswater and Notting Hill it is more common, but is still not frequent. In the northern heights of London—Hampstead, Highbury, Brondesbury, and Stroud Green, it is not common. Elsewhere the disease is exceedingly prevalent within the metropolitan area and also in the outlying suburbs. Along the course of the river rickets is very common, even in the wealthier suburbs of the upper reaches. It is obviously a matter of the first importance to study the conditions which tend to produce these differences. If the child mortality up to the age of five years be taken in four representative metropolitan boroughs, the following striking results are obtained :—

LOWEST AND HIGHEST DEATH RATES FROM ALL CAUSES,* 1911-14.

	During 1st year of life per 1000 births.	For 2nd year of life per 1000 survivors at age of one year.	From 2-5 years per 1000 survivors at age of two years.
Hampstead	74	21.2	20.1
Westminster	92	22.9	21.1
Shoreditch	148	67.1	44.8
Bethnal Green	126	58.6	38.6

In Shoreditch, during the first year, the infant mortality is exactly twice as great as it is in Hampstead ; in the second year it is more than three times as great, and from the second to the fifth year it continues to be more than twice as great as in more favoured parts. It is obvious that what

* " Report on Child Mortality at ages 0-5 in England and Wales." Forty-fifth Annual Report of the Local Government Board, 1915-16.

can be attained in Hampstead ought to be attained in Shoreditch, or, if this is impossible, Shoreditch should be condemned as an area unsuitable for the rearing of infant life. The child has its own individual rights, but to place it on no higher ground than that the child is the most valued asset of the State, it should not be allowed to suffer from the accident of its place of birth. The main contention as to the ætiology of rickets has always ranged round two heads; firstly diet, and secondly general unhygienic conditions, including defective housing and all the evil consequences of confinement, overcrowding, vitiated air and loss of sunlight which such conditions entail. All are agreed that both are important. The question of adequate feeding for the infant is one comparatively easy of solution, and should be solved within a reasonably short time, but the question of housing is a much more difficult problem.

In Scotland, as in England, rickets is again most common in the industrial areas. It is especially prevalent in the great industrial zone lying between the Firth of Forth and the Firth of Clyde, bounded by Edinburgh and Leith on the east coast and by Glasgow on the west. It is exceedingly common in the whole Clyde valley, especially in Glasgow and its suburbs, and in the north of Ayrshire. In the coal-bearing districts adjoining the Firth of Forth it is also common, and the area of prevalence then extends up the east coast as far as Aberdeen. Beyond that it is common in the larger towns lying on the shores of the Moray Firth. It is not common in the south of Scotland and in Perthshire, and it is rare in the Highlands.

Ireland is more favourably placed as regards rickets than either England or Scotland. It is exceedingly common in the populous areas around Dublin and Belfast. Donegal excepted, there is more rickets in Ulster than in the rest of Ireland, probably about to the same extent as it is found in the south of England. Throughout the rest of Ireland rickets is not common. Generally, it may be said that nowhere in the British Isles is rickets unknown, but it is mainly a disease of towns and industrial districts. It is

rare in the rural districts of Scotland, the north of England, North Wales, and Ireland. In the rural districts of Ulster and of the south of England it is more common than in the rural districts elsewhere throughout the country, and it is especially prevalent in Cornwall, Kent and North Essex.

A striking fact is made out on examination of the map of the distribution of rickets throughout Great Britain and Ireland, namely, that the areas of greatest frequency correspond very closely to the distribution of the coalfields throughout the United Kingdom. The distribution corresponds to the results of clinical experience of the disease that it is most prevalent amongst the denser masses of the industrial population. In the report of the Local Government Board for 1915-16, on child mortality at ages 0-5 years in England and Wales, maps are given of the areas of greatest mortality throughout the country, and the important comment is made—"a map of the coal measures of the country would almost serve as a map of the chief areas in which child mortality is excessive." In other words, the areas of the greatest prevalence of rickets and of greatest child mortality correspond within very narrow limits to the areas of greatest density of population and to the geographical distribution of the great industrial centres which have arisen around the coal measures of the country. These are factors of the greatest importance in discussing the ætiology of rickets. Glisson believed that the disease first started in the south-western regions of England, and however that may be, it is certain that rickets is more common at the present time in the rural districts of the south and west of England than it is in the north. Its prevalence in Bath is worthy of note, for, as a rule, the houses are well built and the streets are airy, though the town as a whole lies in a hollow. Mayow, who practised in this city during the seventeenth century, agrees with Glisson as to its prevalence in the south-western counties. Writing in 1855, Schoepff Merei states that the disease is not common in Bristol but that the poor in Bath show a high proportion

of rickets and an appalling mortality. The common occurrence of rickets in the south-western counties of England is a striking fact which has been noted by several writers on the subject of rickets since the year 1650, and it remains as true of this portion of England to-day as it did three centuries ago. These counties are almost entirely rural, the land being partly under agriculture, and partly under pasture, so that they include much of the richest dairy farming country in Great Britain. The reasons for this apparent anomaly will be more fully enquired into in discussing the history of the disease and the classic writings of Glisson.

Two points of interest arise where the disease, as described by Glisson, differs from what pertains at the present time. In the exceedingly accurate anatomical description of the examination of the rachitic cases, the severity of the cases he examined is very striking. Very rarely are such cases seen now in this country, and probably to-day the observer would have to go to the Continent, to such a town as Vienna, to see cases of the extreme degree which he describes. It seems as if the disease in this country, while it has become more common and more widely distributed, has assumed a milder form. It suggests the possibility that, as a result of the enormous growth and the concentration of industries which are taking place in England, a population is being produced adapted to existence under the slum conditions prevailing in our industrial areas. The second point is that Glisson describes rickets as a disease of the idle rich, associated with over-feeding and luxurious living. His observations on this point are confirmed by other observers.

To-day, while the disease occurs amongst wealthy families fairly commonly, it is essentially a disease of the poorer part of the population, who are not only badly housed and live under unhygienic conditions, but who also live on a deficient and a badly balanced diet. As regards the diet, it may be stated broadly that among the poor there is a deficiency of proteid and of fat and an excess of carbohydrates. The insufficiency in the supply of proteid

is much the gravest defect in the diet of the poor, but let it suffice for the present to say that these dietetic factors have no influence in the production of rickets, though naturally the quality and quantity of food have a marked influence in the progress of the disease, once it is established.

During the years 1911-14 the chief causes of mortality at the ages 0-5 in England and Wales, given in percentages, were as follows: congenital debility, 23 per cent.; bronchitis and pneumonia, 19·5 per cent.; diarrhoeal diseases, 15·8 per cent.; measles, 7·3 per cent.; tuberculosis, 5·3 per cent.; whooping cough, 5 per cent. The great majority of deaths classed under congenital debility occurred during the first year, and a considerable portion of these conditions is due to congenital syphilis. In the other diseases, rickets plays an important part, and it can be readily understood that in zymotic infections, such as measles and whooping cough, the already debilitated rickety child with its embarrassed respiration and circulation has a smaller chance of recovery than the healthy child. Diarrhoea is not, in itself, a common symptom of rickets, but the abdominal distension and tendency to catarrh in rickets undoubtedly render the child more liable to infection and make the chances of recovery more remote. It is a general experience in all children's hospitals, that no matter from what condition the child is suffering, if the evidences of rickets are looked for the percentage of rickety cases is found to be very high.

CHAPTER III

THE GEOGRAPHICAL DISTRIBUTION OF RICKETS

Distribution in Europe and Asia

Distribution in Europe.

PROF. BAUMEL, in a paper read before the International Medical Congress at Moscow, in 1897, gave the results of an enquiry he had made from the best known physicians for the diseases of children in the great centres throughout Europe.*

In Paris, for example, Comby finds that rickets is very common amongst the poor, and he states that it is widespread in the following French departments—Nièvre, Calvados, and Seine and Marne. Leroux, taking dispensary figures in Paris for the years 1884 to 1894, found that 1,362 children out of 7,000 to 8,000 patients suffered from rickets. Marfan finds that in the children in hospital in Paris, between the ages of six months and three years, nearly 50 per cent. are rachitic. From the fourth to the eighth year the stigmata of the disease tend to disappear and are only found in one patient out of four. He is of opinion that of late years, while the slight forms have been as common as in the past, the severe forms have seemed a little less numerous.† This last observation is in accord

* "Comptes-rendus du XII Congrès Internationale de Médecine." Moscow, 7th-14th Aug., 1897. Vol. III, Section VI. Published Moscow, 1899. "Distribution géographique du rachitisme." Prof. L. Baumel (Montpellier).

† "Maladies des Os, par Marfan." "Nouveau Traité de Médecine et de Thérapeutique," Brouardel et Gilbert, Paris, 1912.

with experience in London, the disease being as frequent now as it ever was in the past, probably more frequent, but at the same time tending to be of a milder form. Dr. Secheyron and Dr. Bezy state the condition is very common in Toulouse ; in Tours it is also common. (Chaumier.)

Simon, of Nancy, states it is very common in Lorraine, and in Montpellier it is prevalent ; if one examines sick children in hospital for the signs of the disease, it is found in from 50-80 per cent. (Baumel.)

Hirsch notes the predominance of the disease in wet, cold and marshy places, and states that countries with a cold and wet climate, such as Holland, many parts of England, the North German plain, the mountainous regions of central and southern Germany, and the plains and mountainous districts of northern Italy, if they are not the exclusive seats of rickets, are at all events its headquarters. It is common in the wet plains of Lombardy, of Alsace, of Holland, of Belgium, and of North Germany, as well as in the valleys, deeply cleft and traversed by many watercourses, of the Giant Mountains, the Thuringian Forest, the mountainous parts of south-western Germany, and the Alpine foot hills of Austria and northern Italy.*

In Frankfort, Professor Rehn gives the incidence of rickets as from 50 to 60 per cent.† Prof. Epstein says the disease is common in Prague and throughout Bohemia generally, 80 per cent. of the children under two being affected. In Vienna, Kassowitz, who has made a close and detailed study of the disease, states that it is of very frequent occurrence and gives the proportion as 80 per cent. In Buda-Pesth, according to Prof. Bokay, it is also rife. Nauwelaers, of Brussels, says rickets is present in about 50 per cent. of the population of that town, and finds that it is not uncommon in the better classes.

Merei, after many years' experience of rickets, both on the Continent and in England, states in 1855 that in Paris, Vienna and Pesth, cases of rickets abound. It prevails to a

* Hirsch, *loc. cit.*, p. 737.

† Prof. Baumel, *loc. cit.*

great extent in Dresden and Munich, and is indeed common in all the large continental towns. As a result of his experience, he finds that it is much more common in Austria and Hungary than it is in England, and that it is more common in wealthy families on the Continent than in England. This agrees with later experience, and the cases in Vienna seem of a more severe type than is met with in England. In discussing the effects of the late war on the populations of Europe, it is important to remember the extreme prevalence of rickets which has existed all over the Continent for many years. Thus, one report mentions that in a Leipzig home for delicate children after the war, 40 per cent. of the children were found to be rachitic. There seems to be no doubt that the children examined were suffering from severe malnutrition, but the conclusion that is drawn that rickets has greatly increased as a consequence of the war is not justified by the percentage of rickety cases found. Careful examination would probably have revealed a higher percentage before the war.

In Spain, Prof. Borobio says the disease is common in Saragossa. It is also fairly common throughout the north of Spain, down to the Portuguese frontier, disappearing towards the south. In Lisbon, it is not common.

In Italy, Salmon notes that it is commonly seen in Florence, and Prof. Concetti finds it prevalent among the poor in Rome. In the low-lying parts of the provinces of Milan and Pavia it is common; as already noted, it is diffused throughout the plain of Lombardy generally and in the northern heights of Italy.

The endemic nature of rickets in many parts has suggested an infective origin for the disease. Frey * points out its resemblance to tuberculosis, in that it is common in low-lying and damp localities, while it is rare at the sea coast and also at an altitude. It is most frequent, and presents the characteristics of an endemic disease, in humid marshy countries such as Holland and Belgium, in Alsace, and at the mouths of the Rhine, and in the low-lying

* Frey, "Étiologie du rachitisme." Bale, 1896.

parts of Silesia. In speaking of Somersetshire and the western counties of England, it is noted that there is still a marked tendency to its occurrence in the low-lying hollows between the hills. This is found also to be the case in the mountainous parts of northern Italy. At a height the disease tends to disappear.

Maffei,* who devoted many years to the study of cretinism and its distribution, states that rickets in its habitat resembles cretinism; where cretinism prevails, rickets is found, and where neither goitre nor cretinism is present, rickets is but rarely seen. At 3,000 feet and over, according to Maffei, no rickets is met with; between 2,000 and 3,000 feet it is but seldom seen, but between 2,000 feet and 1,300 feet it becomes again more prevalent and is very frequently seen in the low-lying towns and villages among the poor, especially among those who live in damp, confined, and gloomy dwellings.

Excessive moisture and the poisonous air engendered in the damp and sunless dwellings are, according to Maffei, the essential causes of rickets.

In Davos, Volland and Sprengler did not find a single case, although the greater part of the infants were not nourished at the breast and only received very coarse nourishment from the first days of their birth. This agrees with common experience where it is found, that although all the conditions as regards feeding which are commonly supposed to cause rickets are present, but the climatic environment is not conducive to the disease, it remains for all practical purposes absent. On the other hand, when the child is confined in close, small, gloomy, and badly ventilated rooms in a climate such as ours, the disease will inevitably develop, although the mother's milk be ample and her health beyond reproach, and although the mother may herself have free means of exercise outside the close confines of the house.

In marked contrast to this widespread concentration

* "Der Kretinismus in den Norischen Alpen," von Dr. Maffei. Erlangen, 1844, p. 179.

throughout Europe is the almost complete absence of this condition from warmer and especially tropical countries. Palm, who was for nine years resident in Japan, was struck with the absence of rickets in that country, and the enquiry made by the British Medical Association as to the distribution in England suggested to him an enquiry made on similar lines through medical missionaries resident in China and Japan and India as to (1) the presence or absence of rickets; (2) the habits and diet of the people; (3) the climate and sanitary conditions.* The results obtained are of great interest. They are almost entirely negative. The margin of error in the enquiry is reduced to a minimum. The evidence of the observer is usually the result of prolonged experience, and he is, as a rule, well acquainted with the life and habits of the natives. The number of patients suffering from general diseases is mostly very large. Rickets in its more marked forms is not a disease likely to be missed, and the uniform reports from the various sources that the condition is entirely or practically unknown show that the testimony is reliable. These results may be epitomised as shown on the following tables:—

Locality.	Observer.	Presence of Rickets.	Sanitation and Climate.	Food.
CHINA. <i>Manchuria.</i>	D. Christie.	In six years had not seen a single case.	Lat. 41·5° N.	Millet, rice, pork and vegetables. Infants nursed till 3 or 4 years of age.
<i>Mongolia.</i>	G. P. Smith.	Had not seen a single case.	Air dry. Cold in winter, warm in summer. Scrofula and phthisis common.	

* "The Geographical Distribution and Aetiology of Rickets," by Theobald A. Palm, M.A., M.D. *The Practitioner*, Vol. XLV. Oct., 1890.

Locality.	Observer.	Presence of Rickets.	Sanitation and Climate.	Food.
<i>Tientsin.</i>	Dr. Roberts Dr. King.	Rickets almost unknown in this province.	Atmosphere dry and stimulating with bright sunshine.	Practically vegetarians. Millet flour and occasionally rice are chief articles of diet with greens and beans in season.
<i>Peking.</i>	E. T. Pritchard.	Out of many thousands of patients had seen no marked case in three years.	Conditions insanitary. Scrofula and phthisis common.	Poor, largely vegetarians. Rice, millet, flour, beans and vegetables. Children suckled till late.
<i>Peking.</i>	Dr. Dudgeon.	Almost unknown.	Scrofula and tubercle common.	Children weaned very late—three years, sometimes four or five. Rice, wheaten flour, bean curd and vegetables, chiefly salted.
<i>Chichow, interior of North China.</i>	Dr. Macfarlane.	Rickets rare.		
<i>Shantung Province.</i>	W. W. Shrubbsall.	Out of 4,837 patients, only one case of rickets and that slight.	Bright sunshine. Agricultural district. Anæmia and phthisis rare.	Chiefly grain—Indian corn, wheat, millet; beef, mutton, fowls at intervals.
<i>Provinces of Hupeh, Shantung, Szechuen.</i>	W. L. Pruett.	In many years has never treated a case.		

Locality.	Observer.	Presence of Rickets.	Sanitation and Climate.	Food.
<i>Hangchow.</i>	D. Duncan.	In eight years has only seen a few mild cases.	City of half a million inhabitants. Houses of one storey. Sanitation very bad.	
<i>Canton.</i>	J. G. Kerr.	Out of tens of thousands of cases can recall no well-marked cases of rickets.	Dense population. Warm bright sunshine. Anæmia, scrofula, syphilis common.	Rice, vegetables, salt fish and a little animal food.
<i>Thibet.</i>	Dr. Karl Marx.	In two and a half years found no rickets.	High altitude, 11,300 ft.	
INDIA. <i>Kashmir.</i>	A. Neve.	Out of many thousands of patients, about one case of rickets annually.	Populous town, 100,000 inhabitants. Streets narrow. Sanitation bad.	Children suckled for two or three years.
<i>Punjab.</i>	Dr. Hutchison.	After 20 years' practice found rickets very rare.	Houses small and badly ventilated but occupants spend small portion of time indoors.	Maize ground whole, baked into cakes and eaten with some vegetable. Wheat, barley and millet, occasionally. Ghee or clarified butter and oil. Fruits. Rice too dear for common use.
<i>Rajputana.</i>	Wm. Huntley.	Out of 10,000 patients had only one case of rickets.	Air dry. Brilliant sunshine. Sanitation bad.	Grain-eating people. Meat rarely eaten. See dietary given below.

Locality.	Observer.	Presence of Rickets.	Sanitation and Climate.	Food.
<i>Madras.</i>	Dr. Elder.	During 13 yrs. and seeing 20,000 cases annually, never had a case of rickets to show his students.		
<i>Neyoor</i> (South Travancore).	E. S. Fry.	Out of 17,173 patients had one case of rickets.	Sanitation bad.	Food is insufficient. Children suckled till two years old.
<i>Ceylon.</i>	J. D. Macdonald and four others.	All state rickets is very rare, if it exists at all.		Other diseases due to bad feeding are common, <i>e.g.</i> , mesenteric disease, etc.
<i>MOROCCO.</i> <i>Tangier.</i>	Dr. Churcher.	No cases among Moors. Two or three among Jews.	Clear atmosphere. Bad sanitation. Syphilis very prevalent.	
<i>JAPAN.</i>	T. A. Palm.	In nine years' dispensary and hospital practice, unable to recall a well-marked case.	All varieties of climate. Much moisture, but sunshine is brilliant both summer and winter.	Rice and fish. Of late years have begun to eat beef and milk. Fresh vegetables abundant. People are fairly well fed.

Dr. Huntley, speaking of the food of the natives in Rajputana, makes some interesting observations on their dietary. He subdivides it into four classes; I and II being the dietaries of the better fed natives, while III and IV are those of the poorer classes, the last being the ordinary village diet.

	I	II	III	IV
Wheat	1½ lbs.	1½ lbs.	o	o
Pulse	¼ lb.	¼ lb.	¼ lb.	o
Coarse brown sugar ...	2 oz.	2 oz.	2 oz.	o
Butter	2 oz.	¼ lb.	o	o
Butter milk	...	...	ad lib.	little.
Barley	...	...	1½ lbs.	2 lbs.

Rice, on account of its comparative expense, is seldom eaten by the natives, and milk is never drunk by the vast majority of the people. Dr. Huntley believes, with reason, that the nutrient values of these dietaries completely contradict Dr. Cheadle's view that a deficiency of animal fat causes rickets. Mothers in Rajputana are frequently only thirteen years of age. They do not take milk while suckling, and the menses reappear about three or four months after the birth of the child. The child is suckled till the age of two. After six months the young infant is given wheaten porridge. They nurse one child till another comes and then frequently both continue to take the breast.

Later, in discussing the ætiology of rickets, the bearing of these facts will be more minutely gone into, but in the meantime it may be noted that in the vast population of the East and of tropical countries generally, all the factors which are commonly supposed to be the exciting causes of rickets are present in an extreme degree. England is one of the wealthiest countries in the world and rickets abounds; India is one of the poorest but is practically immune. In India, millions live on the verge of starvation and all our efforts are still unable to prevent the death of enormous numbers in recurring times of famine. Under-feeding in this sense of the word is unknown in England. Throughout the East, mothers suckle their infants and wean them late. Frequently they continue nursing during pregnancy and mixed feeding while the child is at the breast is the rule. The diet lacks variety for the great mass of the

population, and taking the East generally, if rice fails nothing can prevent dire distress. Compared with the East, the diet in England is of the most varied kind.

Infantile mortality in the tropics is high. Weaning is a difficult and dangerous period. The great danger of this period is diarrhoea and dysentery from infections with amœbæ or bacilli. Deaths from diarrhoea and dysentery and intestinal toxæmias are exceedingly common, and when they do not end in death, these conditions are apt to be chronic and to influence the health of the child over a long period. But these infections do not end in rickets, as one would expect if it were true, as is usually maintained, that rickets is of the nature of an intestinal toxæmia.

The outstanding feature in the lives of all these vast communities is that their life is much in the open air and there is brilliant sunshine. The huts may be unhygienic, but there is no comparison, as regards health conditions, between the hut of the native village in India, bathed in constant sunshine, and the basement room of a slum dwelling in London, Manchester, or Glasgow, where for from six to eight months the sun is but seldom seen and the weather is dark, cold, and bleak. Speaking of the distribution of the disease in Europe, it was noted that rickets resembles goitre in its distribution, and in certain districts in the Alps the two conditions were frequently found together. In the Himalayas, it is interesting to note that endemic tetany is found in goitrous districts. This disease is characterised by bilateral, intermittent, and usually painful spasms of the hands and feet, and at times other parts of the body, and increased excitability of the nervous system. Tetany is a disease which is peculiarly associated with rickets, and Castellani notes that when tetany is found in the Himalayas, it is frequently necessary to treat the associated condition of rickets.* McCarrison has pointed out that congenital goitre is extremely common in certain Himalayan villages, nearly

* "Manual of Tropical Medicine." Castellani & Chalmers, London, 1919, p. 1922.

every man and woman being affected. The mothers are often myxoedematous and 60 per cent. of infants at the breast show evidence of goitre. The common association of rickets with these diseases has frequently given rise to the speculation that rickets itself may be of an infective nature. The relationship between rickets and endemic goitre will be treated at greater length in discussing the ætiology of rickets.

CHAPTER IV

THE GEOGRAPHICAL DISTRIBUTION OF RICKETS

Distribution in the Colonies

Rickets in South Africa.

FROM personal observations made up country by the author during the years of the South African war and afterwards, and from a wide experience of the country, rickets even in its mildest form is exceedingly uncommon in the immense elevated plateau, of which the Karroo forms so great a part. This applies to native children and to the offspring of Dutch and English parentage alike. With mothers belonging to the European stocks lactation is often a matter of difficulty, and is frequently cut short at an early date owing to failure of the breast milk. Even when the mother continues to nurse her infant, the dietary usually requires to be supplemented with other food in the early months. Dairy produce is scarce, and the diet, especially with the Dutch community, consists largely of bread, meat and coffee. The conditions affecting the adult are largely of a rheumatic nature, not acute rheumatism, but the chronic forms usually classed under the term muscular rheumatism and fibrositis. Chronic indigestion is frequent. Dysentery and diarrhoea in young infants are common, and marasmus and other wasting diseases are by no means infrequent, especially among the children of European parentage. Young infants have often to struggle through periods of great difficulty in their alimentation during the early months of their lives. But these cases do not end in rickets. Up country tuberculosis is uncommon, though it is increasing in some of the seaport towns, such as Port Elizabeth. Prolonged droughts tell severely on the

health and spirits of the sparse population occupying the vast territory of the Karroo, but the outstanding characteristics of the climate are the rarefied air of the high elevation and the brilliant sunshine, which lead to a high degree of diaphaneity. This renders the great heat comparatively easily borne. In South Africa, though the sunshine is brilliant and the heat often intense, much time can be spent in the open air, and sunstroke and heat stroke are rare. Tennis and other active games can be played even without headgear, whereas in India it would be dangerous to cross a road without effective protection to the head. This is due to the fact that the rarefied air does not retain the heat as does the heavier air of, say, the Deccan, in India—a great plain but little raised above the sea-level. Under such conditions as prevail in the Karroo, it is practically impossible to produce rickets, no matter what deficiencies and errors occur in the diet of the infant, and these are many.

Writing in June, 1920, in response to an enquiry from the author as to the prevalence of rickets, Dr. J. Galloway, part time Medical Officer of Health for Port Elizabeth, Cape Colony, who has had many years' experience of medical practice in the city, states: "I have seen a very few cases of rickets during my whole experience in Port Elizabeth. Here and there have been cases of a very mild type. I have never seen a case which you could diagnose at a distance as rickets."

From East London, Cape Colony, Dr. Ernest Hill, Medical Officer of Health, writes in July, 1920, in response to a similar request: "I have made enquiries of the doctors practising in this town, and the general opinion is that rickets scarcely ever occurs in any section of the community, but one doctor, who has been in practice for a great number of years, replies that it occurs fairly frequently in the poorer class of whites, occasionally in the well-to-do, rarely in natives living in the country, and occasionally only among those living under urban conditions."

The notable immunity of the South African native,

although he has been under the influence of European races since the beginning of the seventeenth century, is very remarkable, when it is considered that the American negro suffers severely from the disease. In South Africa, however, the white man came to the country of the native, while in America the negro was removed from his home and natural surroundings and was transplanted into an entirely unnatural environment, where in course of time the population concentrated into great industrial centres. The explanation lies in the different circumstances under which they live in these two countries. In South Africa the distinction between black and white is still very strictly drawn, and the coloured portion of the population still retain many features of their native life.

The native, as a rule, lives in a settlement outside the town usually known as the location. Even the domestic servants return to the location at the end of the day's work. According to the class of native, the houses vary from mere huts to fairly well-built houses, but the life approximates to the native state and is not at all comparable with the life of the slum areas of large American cities, in which the native tends to occupy the worst part. As regards food, the South African native frequently does not fare so well as the American negro either as regards quantity or variety. A large proportion of the food for the locations is carried home from the leavings of the not over-abundant table of the white man. Even the best of breast-feeding does not protect the negro infant in America from the onset of severe rickets.

From Durban, in Natal, Dr. Norman H. Walker, Assistant Medical Officer of Health, writes in August, 1920, in answer to an interrogation addressed to him on the subject: "Enquiries which I have made from local practitioners suggest that rickets is not a common disease in Durban or Natal. Such cases as are met with are of a mild type, and the disease is scarcely ever found in members of the better class. One doctor expressed the opinion that he had more cases in Indians than in natives."

Rickets in Australia.

The study of rickets in Australia is one of great interest and importance. Most clinicians find difficulty in believing that the disease first rose in England at the beginning of the seventeenth century, and have dismissed Glisson's original statement to this effect without any real enquiry into the subject.

In Australia to-day can be witnessed the onset and growth of this disease, which is not indigenous to the country, but which is increasing for precisely the same reasons as it arose and spread in England, namely, the growth of dense populations and slum areas. Not that all these cases occur in slums, for, as has been previously shown, it is easy to reproduce the conditions of vitiated air, deficient sunlight, and want of exercise in the homes of the wealthy. But the great mass of the well-marked cases comes from slum areas where overcrowding is the constant and predominant feature. It is the more remarkable in Australia because the climate is not at all favourable to the growth of rickets. On examining the map, it will be found that the more thickly populated areas lie in the south-eastern corner of the continent, near the coast in the states of Queensland, New South Wales, Victoria and part of South Australia. Roughly, this thickly populated area lies between 27·5° south latitude which passes through Brisbane and 39° south latitude which touches the southernmost point of the continent. In Europe, this zone is comparatively free from rickets. The distribution of the population in Australia shows one peculiar and unfortunate characteristic which is of great economic importance, and that is that of a population of less than 5,000,000 there are 2,000,000 living in the capitals of the various states. The exact proportion for the four chief states is shown on the next page.

It will be noted that in New South Wales, with much less than two millions of a total population, considerably more than three quarters of a million live in one huge city, Sydney.

Such a state of affairs is naturally not a desirable one, for so great a town population can hardly expect to find industrial occupation provided for it by a population which is but little in excess of the number spread over the whole state. Naturally, this leads to unemployment and poverty with all its attendant evils, crowded, unhygienic, and squalid domestic surroundings, associated with poor feeding. Sydney, it must be remembered, is already an old town. It was a considerable town in the days when, in the home country and elsewhere, but little or no attention was paid to town planning and houses were allowed to grow up haphazard. The streets are irregular in width, many of them narrow and close together, and Sydney has consequently more the

LAST CENSUS OF COMMONWEALTH, 1911; ESTIMATED
POPULATION, DECEMBER, 1916.

State.	Population.	Chief City.	Population.	Proportion of population of Chief City to whole State.
New South Wales	1,855,908	Sydney ...	764,000	41·15 per cent.
Victoria	1,399,779	Melbourne	695,000	49·10 "
Queensland ...	669,467	Brisbane	168,393	25·15 "
South Australia...	431,814	Adelaide	223,718	51·59 "

appearance of an old world town than any other city in Australia. It stands in the centre of a great coal-bearing basin, and is naturally the seat of numerous manufactures, to the prosperity of which the abundance and cheapness of coal have been conducive. Besides shipping and railways, there are tobacco factories, flour mills, boot factories, sugar refineries, tanneries, meat preserving and soap works. Carriages, pottery, glass and furniture are made. The population of Sydney has increased with marvellous rapidity. In 1861, it was (city and suburbs inclusive) 95,000; in 1881 it had increased to 237,300, and in December, 1916, it was estimated at 764,000. Such a rapid increase is attended with considerable risk to the health of the community.

But while Sydney is the oldest city in Australia, it has many natural advantages. It is beautifully situated on the shores of Port Jackson in latitude $33^{\circ} 51'$ south. It has a mean temperature of 63° Fahr., and the range of temperature between mean summer and mean winter temperature is 17° Fahr. The rainfall is about 50 inches. The skies are clear and the prevailing state of the weather is characterised by a genial warmth. Such conditions are not conducive to the onset of rickets, but the important lesson is again pointed out that the best surroundings can be perverted by want of knowledge or carelessness. Even to-day, in England, the population generally, while it feels vaguely that something must be done to improve the comfort of the home surroundings of the worker, is not yet impressed with the fact that should by this time be abundantly obvious, that until our slum areas have been swept away no great improvement can be expected in the health of the industrial labourer and of the poor. A truly enormous task, but the magnitude of the evil is likewise very great, and means not only chronic ill-health and blighted opportunities to the individual, but entails a very great economic loss to the State.

The standard of life is altogether higher in Australia than it is in the home country. The food is good and wholesome and is on a more generous and ample scale than at home. Cases of actual want are very rare. There is not the same ignorance as regards dieting as is found amongst the very poor in England. The life of the child, and indeed of the population generally, is spent much in the open. But the evil effects of crowded and unwholesome environment are concentrated on the young infant in the first few months of its existence. When it is able to move about by itself, say at the age of two years, the child participates in the advantages of the more open-air life, and on this account prolonged and severe cases of rickets are but seldom seen. The disease in Australia is of a very mild type. There is no essential change or improvement in the child's diet at, say, the age of two, but immediately it is left to its own resources and is not entirely dependent on the mother for the oppor-

tunities of fresh air and exercise, which the mother of the poor seldom has leisure to give, the child begins to make rapid headway towards recovery from the condition. In Melbourne, poorer quarters and mean narrow streets also exist, but not to the same extent as in Sydney. It is also a great manufacturing centre, tanning, wool washing, bacon curing, flour milling, brewing, iron founding, etc., being considerable industries.

The prejudicial effect of city surroundings on infant life in Australia, as at home, is evidenced by the mortality being markedly heavier in urban than in country districts. In Victoria, on the average of the past five years, the deaths of children under one year of age to every 1,000 births in the large towns, were 77 in Melbourne, 83 in Ballarat, 74 in Bendigo, and 70 in Geelong, as against 55 in the rest of the state. In Greater Melbourne, the varying death rate for the various metropolitan boroughs speaks eloquently of the pernicious effects of overcrowding. The deaths under one year per 100 births during 1918 varied from 11·90 in Port Melbourne City to 4·98 in Kew Town.* The centres having the lowest death rate were residential, whilst those with the highest death rate were the most thickly populated.

The death rate from rickets, as one would expect, is exceedingly small. Mr. A. M. Laughton, Government Statistician to Victoria, informs me that in Victoria during the ten years from 1910 to 1919, 51 deaths occurred from this disease, 32 males and 19 females, and of these, 42 died under the age of two years. A. Jeffries Turner, writing in 1892, draws attention to the infrequency of rickets in Australia as compared with European cities. Improper feeding, he believes, is not the exclusive cause of rickets, for improper feeding is as common in Australia as in England. Turner gives the following reasons for the disease being less common in Australia : (1) children of two years and upwards are better fed and recover more completely and more rapidly on that

* "Victorian Year-Book, 1918-19," by A. M. Laughton, F.S.S., Government Statistician.

account ; (2) the warmer climate leads to diminished consumption of hydro-carbons and proteins and so renders the relative deficiency less injurious ; (3) abundance of fresh air ; life in the open ; wooden houses ; abundance of sunlight.*

In 1889, Dr. Springthorpe† states that owing to the absence of abject poverty and of profound dietetic ignorance, rickets is practically unknown amongst Australian children. That was written over thirty years ago. In 1908, speaking of the disease in Sydney, Dr. W. F. Litchfield comes to the following conclusions : (1) rickets does occur in Sydney, but it is not a common disease ; (2) the disease, where it occurs, is generally of a mild type, enlargement of the ends of the long bones being rare in the active stage ; (3) the number of cases requiring surgical interference is very small ; (4) deformity of the pelvis sufficient to obstruct labour is rarely, if ever, seen.‡

In a report by the Medical Officer of the Victorian Education Department, 1911–12, the results are given of a careful enquiry into the presence of rickets in school-children in Melbourne. The signs of the disease were systematically looked for in a whole series of children. The results are noteworthy. Out of 1,327 boys examined, 355—that is 26 per cent.—showed rachitic signs, such as deformities of the chest and spine, knock knee, or bow legs, square shape of the head, beading of the ribs, pot belly, and enlarged liver and spleen. That is to say, that a quarter of the school-children examined were suffering from rickets or had suffered from rickets of a mild form. In the opinion of the writer, this explains why, with all the children sitting at the same desks, only some show deformities due to postural influences. He notes two types : (1) the precocious, bright, nervous child, usually thin and weedy, prone to constipation and indigestion and with a capricious appetite,

* *Australian Medical Gazette*, January, 1892, p. 104.

† "Hygienic Conditions in Victoria," by J. W. Springthorpe, M.D., M.R.C.P.

‡ "The Incidence of Rickets in Sydney," by W. F. Litchfield, M.B., Australian Medical Congress, October, 1908.

often excessive ; (2) the solid type, often fat and flabby and over-weight, and yet nervously unstable. These are the backward children.

The report attributes the condition to two factors, namely, defective feeding and defective hygienic conditions, such as overcrowding in ill-ventilated rooms and the breathing of vitiated air. It is pointed out that marked rickets is more common amongst children fed on artificial foods than in those who are breast fed. This is well known, but it is also to be noted that the breast feeding is no protection against the onset of the disease. It should also be remembered that the child is not rickety because he has been fed on artificial food, but is very frequently taken off the breast and placed on artificial food because he is suffering from a rachitic form of mal-nutrition and does not thrive. As previously stated, when the child is exposed to the evil conditions which produce rickets, breast feeding will not save it from the disease, though it will in all probability modify its severity ; and on the other hand, a native child living in the East under native conditions may, and frequently does, have every conceivable error made in its diet and suffers severely accordingly, but it does not develop rickets. Even in Australia, it is found that a considerable proportion of breast-fed babies are rickety.

In August, 1920, Dr. Harvey Sutton, speaking of New South Wales, finds that 25 per cent. of ordinary school-children showed slight but definite signs of rickets.* Dr. Sutton believes that overcrowding (less than four rooms) and artificial feeding in the first six months, are responsible for most of the severe forms. He notes the curious fact that there is a lower percentage of rickety cases, however, when the artificial feeding begins at birth. In these cases the probability is that the child, under medical advice, is placed on a properly regulated regimen and thrives in spite of the artificial feeding.

* " Manifestations of Rickets in School-Children," by Harvey Sutton, O.B.E., M.D., Principal Medical Officer, Department of Public Instruction, New South Wales.

What plays havoc with the infant's health is when the anxious mother, usually on the advice of kindly neighbours, tries first one food and then another, changing from cow's milk to dried milk, and from one form of dried milk to another, and from that to condensed milk. Nothing is more important in infant feeding than system and regularity, and the medical man is frequently at fault in that he leaves the decision of such an important matter to the judgment of an inexperienced and anxious mother. Dr. Sutton points out that hypoplasia of the teeth is not nearly so common in Australian children as in English children. He states he is frequently able to assert that a child is an immigrant solely because of the appearance of the teeth. Now these various careful observations, made at different periods during the last thirty years, tend to show that rickets was not originally a serious factor in infant life in Australia, but that it is rapidly becoming one of great importance, for even mild rickets has far-reaching results. There is no reason to suppose that the quality of the food, either for the mother or for the infant, has deteriorated in Australia during that time; indeed the reverse is true.

INFANTILE DEATH RATES FROM CERTAIN CAUSES,
1891-3 and 1918.*

Cause of Death.	Deaths under one year per 1,000 Births in—	
	1891-3.	1918.
Diarrhoeal diseases, all forms ...	29.66	11.90
Wasting diseases (marasmus, atrophy, etc.) ...	22.24	13.58
Bronchitis, etc. ...	11.37	6.39
Convulsions ...	6.83	1.08
Total ...	70.10	32.95

Vital statistics show that the health of the nation has improved. The increase in the incidence of rickets has

* *Loc. cit.*, p. 198.

advanced at the same time that there has been a very remarkable reduction in child mortality. A comparative study of the deaths from certain causes for about thirty years ago and to-day gives the above results. That is to say, the mortality from these diseases is now much less than half what they were thirty years ago. This is due to better sanitation, better food supply, and to a large extent to a more intelligent nurture of the young infant by the mother. The development of skilled nursing during the period of confinement, and in later years, the free dissemination of education in matters of child welfare have had a wonderful effect in reducing infant mortality both at home and in the colonies. Unfortunately, with this steady improvement, there has been a large access of overcrowding due to the increase in density of the populations in the large towns, and this has had a distinctly harmful effect on the development of the child.

In South and West Australia, rickets, as might be expected, is quite uncommon. Dr. H. R. Pomery, in answer to a query on the subject, writes in August, 1920, from Franklin Harbour, South Australia, that rickets does not occur in this part of Australia, and he states that in South and West Australia generally, it is recognised as a very rare disease indeed. Writing in July, 1920, the Government Medical Officer in charge of the Wallaroo Hospital, South Australia, states that in twenty years' residence in Wallaroo he has never seen a case of rickets nor has any case been admitted during the sixteen years he has been in charge of the hospital. The hospital is the only Government Hospital between Port Pirie, which is 60 miles north, and Adelaide, 100 miles south; to the west there is the unlimited expanse of West Australia, while Clare, Burra, and Kapunda hospitals lie 80 miles to the east. There are copper mines situated within this area but there are no slums. In these great and sparsely populated areas, with a genial climate, blue skies and brilliant sunshine, the conditions for the production of rickets do not exist.

Before passing from the disease as it affects Australia,

it may be noted that systematic observations, such as those recorded in the report of the Medical Officer of the Victorian Education Department, 1911-12, and in the report of Dr. Harvey Sutton, in New South Wales, are of the greatest value. The cases recorded are all mild cases, and as such are very likely to escape the eye of the practitioner and will certainly escape the observation of the parent. Only a systematic examination of the child, actually looking for evidence of the disease, would reveal the existence of these cases. It would be of the greatest value if a world census of young school children and infants could be made as regards the incidence of rickets. Two things are essential for a complete examination, firstly, that the child should be stripped as far as the waist, and secondly, that the mother should be present to give essential details in the history, such as the date in cutting the first tooth and the age of the child when it began to walk and speak, besides particulars of feeding during infancy.

Rickets in New Zealand.

The climate of New Zealand is in all parts a very healthy one. The air is clear and stimulating with ample sunshine. The population is nowhere dense and is situated mainly on or near the coast line, where the chief centres lie. New Zealand to-day is probably the most healthy country in the world. It is conspicuous as showing the lowest death rate of the Australian States, the rates for which are considerably lower than those of other countries. From 1896 to 1906, the death rate varied from 9 to 10·50 per 1,000, and in 1912 the remarkably low death rate, the lightest in the world, of 8·87 per 1,000 of mean population was reached. The infant mortality is very low.

The proportion of deaths of infants under one year to every 1,000 births is as follows :—

1910	...	67·73
1911	...	56·31
1912	...	51·22
1913	...	59·17

with an average for the ten years up to 1913 of 65·03.

The following table shows that, as regards the preservation of infant life, far better conditions obtain in New Zealand than in most other countries :—

Country.	Year.	Rate of infantile mortality under 1 year per 1,000 births.	Birth rate per 1,000 of mean population.
New Zealand ...	1911	56	26
Australian Commonwealth	1911	68	27·2
England and Wales	1911	130	24·4
Scotland ...	1910	108	26·2
Ireland ...	1911	94	23·2
France ...	1910	111	19·6
Belgium ...	1910	134	23·7
Germany ...	1911	192	28·6

At home, those deaths under one year are often looked upon as largely inevitable owing to the child, from its very birth, not being adapted for the maintenance of an independent existence, either as the result of congenital disease or of some inherited weakness of constitution. The low death rate of New Zealand compared with that of England, Belgium and Germany, shows that environment is responsible for a very large part of this mortality. In England, the conditions as regard climate are extremely unfavourable when compared with the weather conditions which prevail in New Zealand. It is exceedingly difficult in England for the children, even of the wealthy, to escape entirely from the onset of rickets during the long and dreary winter months. The weather conditions of New Zealand cannot be reproduced at home. All the more it is necessary to see that the children of the home country are placed in the most favourable position possible as regards housing and environment, so that as much fresh air and sunlight as are available may reach them during the long tedious winter months.

The regulation of the feeding is comparatively a simple matter, but when a family of six is accommodated in two or three rooms in a crowded street or alley, the difficulties in the way of the mother providing a healthy regimen for

the infant, as regards proper ventilation and exercise, seem well-nigh insurmountable. Rickets is a factor of no importance at the present day in New Zealand. Writing on 3rd September, 1920, Dr. T. Fletcher Telford, Medical Officer of Health, Christchurch, writes as follows: "With reference to your enquiries regarding the prevalence of rickets in the Canterbury-Westland health district, out of 87 replies received in this office from practitioners in this district, in response to circulars issued from this office, no less than 69 have not seen a case of rickets during their period of practice in New Zealand. The remaining 18 have seen this disease, but not frequently, their cases being noticed in immigrants arriving in this country, those from England coming from the industrial parts in particular. You will see from this report that rickets is a disease of moderate rarity in this country. The more roomy housing conditions, with larger open spaces and abundance of sunshine, helps largely to militate against its incidence. Further, immigrants domiciled in this country adopt a much higher standard of living. The wages are very good, and labour being scarce, there is a constant demand for this type of worker, so that there is no occasion for any serious loss of time, leading to poverty with its painful effects in the form of shortage of food and ill-nutrition." From Wellington, the Chief Health Officer writes in a similar strain under date 16th July, 1920: "In reply, I have to state that in New Zealand as a whole, rickets is an extremely rare disease." As regards Wellington City, the District Health Officer reports as under: "Personally, I have only seen one case of rickets during the last six years. I have, however, made enquiries from several Wellington practitioners and have been informed that, although occasional cases do occur, the disease is very rare in Wellington. One practitioner stated that a case came under his notice about a year ago, and a second practitioner stated that he had not seen a case for over five years."

Writing on 14th July, 1920, the District Health Officer, Dunedin, writes: "Your questions *re* rickets

in respect of Provinces of Otago and Southland, New Zealand: (1) there are very few slum areas, and rickets is extremely rare; (2) among the well-to-do, it is also extremely rare; (3) when present it is of a mild type only.

"The general practitioner fifteen years ago saw an occasional case of mild rickets in babies, head sweating, slight bony thickening, etc. Marked deformities are almost unknown, either affecting the long bones or pelvis. These mild cases occur mostly in artificially fed babies, both rich and poor. Of late years infant feeding has improved and rickets is very rare.

"These remarks apply, I think, for New Zealand generally. Air space is good and infantile mortality rate just under 50. Our difficult labours (bony) occur only with women from the Northern Hemisphere."

CHAPTER V

THE GEOGRAPHICAL DISTRIBUTION OF RICKETS

Distribution in America

IF a map showing the density of the population in the United States be studied, the greatest density will be found to exist in the Eastern States. In 1900, eight states of the Union had a density exceeding 100 persons to the square mile: Ohio 102·0, Maryland 120·5, Pennsylvania 140·1, New York 152·6, Connecticut 187·5, New Jersey, 250·3, Massachusetts 348·9, Rhode Island 407·0. The centre of population* has tended to move rapidly westwards, and in 110 years has moved more than 500 miles, almost exactly along the 39° parallel of latitude. That is to say, it has passed from 76° longitude in 1790, about twenty-three miles east of Baltimore, to 86° longitude, in the southern part of Indiana, in 1900. Passing from the Atlantic coast westwards the population continues very dense up to about the 90° longitude; between 90° and 100° longitude it becomes less dense, and from 100° longitude to the Pacific coast the population is sparse till California is reached, when it again becomes somewhat dense, though to a much less extent than on the Atlantic side.

As regards climate the United States may be divided into three distinct regions:—

1. the Atlantic slope and great central plain possess a climate distinguished by great extremes—low winter temperatures alternating with high summer heats. There is abundant rain, ranging from 13 to 30 inches annually, the north-east being the rain-bearing wind. In this region rickets is exceedingly prevalent:

2. the Rocky Mountain zone has a climate which is continental in its character. In the physical appearance of the country, the rarefaction of the air, the brilliant sunshine and the comparative absence of rain, this region resembles the elevated plateau of South

* The centre of population is a point through which, if a line be drawn east and west, there will be as many people to the north as to the south of it; if a line be drawn through it running north and south, there will be as many people to the east as to the west of it.

Africa. The diurnal variation of the thermometer is extreme, and the annual rainfall varies from 3 to 20 inches. In this region rickets is an uncommon condition, even in its milder form :

3. the Pacific slope enjoys a genial, mild climate with abundant sunshine. The rains are periodical, falling in winter and spring. In this region rickets is present, although not nearly to the same extent as on the Atlantic slope, and the type of the disease is very much milder.

If the nineteenth century was remarkable with regard to national and urban growth the world over, it was particularly so in the United States of America. The first general census in 1790 showed a population of 3,929,214 ; by 1900 it had grown to 76,304,799. The average rate of increase has been over 30 per cent, for each decade.

The proportion of population living in cities seems to have been practically constant throughout the eighteenth century and up to 1820. The marked tendency towards concentration in cities and the growth of great towns has been a result of industrial expansion and the developments of railroads since that date. In 1790, out of 100 persons 3 lived in cities and 97 in the open country or in small villages ; in 1840 the ratio of urban to rural population was 9 to 91 ; in 1890 it was 29 to 71.

Rickets is not, so far as is known, a disease indigenous to America. Bones in ancient graves in California, in the north-west coast, and in Peru and other localities in South America do not show any signs of disease, even though examinations of extensive osteological collections have been made. It has arisen and made rapid progress as great industrial centres have developed throughout the country. It is essentially a disease of the great cities and it prevails chiefly in the densely populated areas lying in the eastern portion of the United States. As one passes westwards the disease tends to disappear ; in the more densely populated parts of California it reappears, but only in a very mild form and with a frequency not at all comparable to what obtains on the Atlantic coast.

Among the negro population the results have been

very disastrous, so much so that in certain great cities it is stated that no negro infant escapes, while the disease is frequently of a severe type. "Rickets," says Findlay in the Introductory Historical Survey,* "would seem to be unknown when savage races live under natural conditions, but exceedingly rife when these peoples dwell in civilised countries, *e.g.*, in New York, where one hardly sees a negro child without some evidence of the disease. The same is a striking feature here (*i.e.*, in Glasgow). I do not recall ever seeing a non-rachitic half-caste negro child. It is notorious that these native races in civilised countries inhabit the worst quarters of our towns." In a private communication addressed to me by Dr. Clifford G. Grulee, of Chicago, under date April, 1920, he writes, "Of interest to you, probably, would be one fact which I feel confident to state, and that is, that in a large experience with negro babies in Chicago, I have never seen one between the ages of six and eighteen months, whether breast or artificially fed, that did not have very definite signs of rickets." In a subsequent letter, dated May, 1920, Dr. Grulee writes, "My experience with the Italians and Greeks in Chicago conforms very well with that of yours in London. A thing which strikes me forcibly is that the Italians and Greeks have their habitat in a much warmer climate, and it is amongst these races that we certainly get the largest percentage of cases and also the severest types. With us the negroes, Italians and Greeks form a part of the population which is confined very largely to the slums, but on the other hand, among the Slavic races, such as the Poles and Bohemians, rickets certainly has not the tendency to be so severe, and I question whether the involvement of the children of these races is so universal."

In the East end of London, where there is a very large Polish population, my experience has been that though the type of rickets is undoubtedly much less severe, the frequency of occurrence of the disease is much the same as among other slum dwellers in that area, that is, about eighty

* "A Study of Social and Economic Factors in the Causation of Rickets." Medical Research Committee, National Health Insurance. London, 1918.

per cent. The Polish section of the community in the East end of London is almost entirely Jewish, and the excellent nutrition of these children modifies the type but not the rate of incidence of the disease. In America the disease has long been rampant amongst negroes. Writing in 1894, Acker* states that in the towns all over the United States negroes are almost without exception rachitic. Negroes belong to the lowest stratum of society, and all the evil influences which produce and aggravate the disease are present in a concentrated form. They occupy the worst quarter of the town and suffer from impure air from overcrowding and want of sanitation. They are prone to intemperance. Clothing is insufficient and food is scanty and of poor quality. The mothers nurse their babies irregularly, as many of them are in service during the day. In Buffalo, Snow, discussing the incidence of the disease amongst Neapolitan children, found that seven-tenths of these infants suffer from rickets.

Unfortunately, no general survey has been made of the disease throughout the whole country and statistics are not as a rule available. Rickets in America is not, among the native born, of so severe a type as in Germany, Austria, and Switzerland,† and on that account probably has not excited the same interest as in Europe, where its great frequency and grave consequences have long compelled the attention of observers. In 1899, J. L. Morse made a systematic enquiry into the incidence of rickets in 400 consecutive infants under two years, who were attending as medical out-patients at the Infants' Hospital in Boston.‡ Eighty per cent. he found showed more or less marked signs of the disease. In sixty-one per cent. of the children the feeding was either wholly or partially from the breast—eighteen per cent. wholly and forty-three per cent. partly. The only factor, according to Morse, acting on all alike was im-

* "Rickets in Negroes," by Geo. A. Acker, M.D., Washington, D.C., *Archiv. of Pediatrics*, Vol. II, 1894.

† "The Diseases of Infancy and Childhood," by Henry Koplik, M.D., London, 1919.

‡ "The Frequency of Rickets in Infancy in Boston and Vicinity," by John Lovett Morse, *Boston Medical and Surgical Journal*, 1899.

proper hygienic conditions, and these he considered were the most important causes in Boston and its vicinity. The rachitic rosary he found to be one of the commonest and earliest and most reliable signs. Next most common was delayed dentition.

This proportion, eighty per cent. of rachitic cases occurring among the out-patients of the Infants' Hospital, Boston, seems very large, but it must be remembered that Boston is already an old city, dating from 1630, and though many of the conditions prevailing in the old town, such as tortuous and narrow streets and insanitary houses have largely been done away with since the great fire in 1872, many of the characteristics of the old colonial town still exist. East winds are keen and cold and render a climate otherwise healthy somewhat trying to young infants. The concentration of population in and around Boston is very great, so that in 1900 the territory within fifty miles of the city contained almost three millions of inhabitants—a population second only to that in the corresponding area round New York. Later it will be noted that Dr. Grulee, of Chicago, believes that among the poorer classes of Chicago the proportion is much the same as Dr. Morse found in Boston. Prof. Hess, who has devoted much attention to scurvy and to rickets in children, believes that in the temperate zone the great majority of children suffer from rickets. In his work on scurvy he states, "In any metabolism study of infantile scurvy great care will have to be exercised that the disorder is not complicated by rickets. The danger of this complication may be realised when we bear in mind that the majority of infants have rickets to some degree."* J. Lewis Smith quotes some observations made by Dr. John S. Parry, of Philadelphia, in 1872, who found that twenty-eight per cent. of the children who came under his care between the ages of one month and five years in the Philadelphia Hospital suffered from rickets.†

* "Scurvy, Past and Present," by Alford F. Hess, Philadelphia and London, 1920.

† Article on Rickets in "Ashhurst's Encyclopædia of Surgery," Vol. VII, London and New York, 1895.

The following observations are the result of an enquiry addressed by me to the Bureau of the Public Health Service in Washington, to the Public Health Departments of the various States and to private practitioners throughout the country during the year 1920.

Dr. W. H. Davis, Chief Statistician for Vital Statistics, Bureau of the Census, Washington, informs me that the number of deaths in the registration area of the United States in 1918 was 564. This of course, for reasons already stated, is no criterion of the frequency of the disease, but the distribution of these deaths throughout the various registration areas gives a fairly accurate clue as to the states in which it is most prevalent.

In order of frequency, the first six states lie wholly in the eastern portion of the Union, as follows :—

Area.				Number of deaths from Rickets, 1918.
Pennsylvania	...	...	...	93
New York	...	...	...	72
Massachusetts	...	...	...	36
Illinois	...	...	...	34
Michigan	...	...	...	33
Virginia	...	...	...	31

The following six states, lying wholly to the west, show the lowest mortality :—

Area.				Number of deaths from Rickets, 1918.
Utah	...	...	...	0
Montana	...	...	...	1
Colorado	...	...	...	2
Oregon	...	...	...	3
Washington	...	...	...	4
California	...	...	...	6

For the sake of clearness, and to avoid reiteration, the following communications from various sources have been arranged in tabular form. In the absence of systematic surveys these remarks must, for the most part, be taken simply as expressions of personal opinions and not as official statements :—

Locality	Observer	Remarks
Chicago, Illinois.	Clifford G. Grulee	Among poorer classes percentage of rickets would agree with statement of Dr. Morse as to frequency in Boston, <i>i.e.</i> , 80 per cent. Even among better class, if rachitic rosary is a criterion, it is present in probably at least half of the children. Negroes, Italians and Greeks inhabit slums and suffer severely. Very doubtful if diet alone can cause rickets.
Milwaukee, Wisconsin.	Geo. C. Ruhland, Commissioner of Health	Well-to-do fairly free from rickets. Essentially a disease of poorer districts. Particularly frequent among foreign population, Greek, Polish, Russian Jew and Italian.
Newark, New Jersey.	Julius Levy, Director Child Hygiene Division	Rickets very common among negroes and Italians, developing among breast-fed as well as among those artificially fed. Has seen disease develop among negroes when feeding was adequate, hygienic surroundings good. Believes that defective feeding rather than unhygienic surroundings is cause of condition.
Baltimore, Maryland.	John S. Fulton, Secretary Department of Health	Concerning rickets visible at a glance, it is much more common among negroes than among the white population.
Minneapolis, Minnesota.	Chas. E. Smith, Jr., Executive Officer State Board of Health	1. Believes rickets is less prevalent among poor in slum areas than among well-to-do, because the poor breast-feed their babies. 2. Most of the cases, even among well-to-do, are due to artificial feeding. 3. Negro population is very prone to rickets. 4. Type of disease not so acute as in the eastern portion of the Union.
Jefferson City, Missouri.	Geo. H. Jones, Secretary Bureau of Vital Statistics	Disease is of a mild type, and is more frequent among the poor in slum areas and the negro population.

Locality	Observer	Remarks
Cleveland, Ohio.	R. J. Ochsner, Chief Bureau of Child Hygiene	Among the poor there is a moderate degree of rickets, among the well-to-do somewhat less. Greater proportion present among the Italian population, still larger among the negroes.
Sacramento, California.	Irving R. Bancroft, Executive Officer State Board of Health	Rickets is so negligible in California that the State Board of Health has never attempted to amass statistics of any sort on the disease. The variety of food consumed is such that cases are negligible.
Los Angeles, California.	R. J. Scott, Jr., Hospital for Babies, L.A.	Has seen rickets in Italian and Mexican races quite frequently, less frequently among Japanese. Only very rarely are even slight signs seen in well-to-do class.
„	R. E. Ramsay	Disease present in all classes of society, but is of a milder type than is seen in the Eastern States. Racial factor here is not so pronounced. Distinction between rich and poor as regards means of living not important, as sunlight and fresh air are so generally available for rich and poor alike. Records of Los Angeles County Hospital during 7½ years ending June 1, 1920, show 28 cases diagnosed as rickets, 6 of these being uncomplicated, while 7 showed rickets complicated by bronchitis, otitis media, etc. Parentage: 13 American, 6 Mexican, 2 negro and 1 each of various nationalities. The diagnosis of rickets in this series, small as it is, rests often on slender foundation, pointing to the apparent mildness of rachitic manifestations. The small number of cases recorded in this period in a great general hospital, whose admissions total 15,000 annually, is a graphic intimation of the infrequency of rickets in Southern California.

Rickets

Locality	Observer	Remarks
Los Angeles, California.	C. Edgerton Carter	Among well-to-do thinks rickets fairly common, judging from occurrence of such signs as flat foot and loss of health tone, but without classical signs of disease.
"	Albert L. Hill	In slum areas severe cases very infrequent, hardly enough to secure good teaching material. Cases showing a tendency to rickets more common but still not frequent. Among the well-to-do, very infrequent.
"	Ezra S. Fish	Rickets not prevalent and not severe.
"	W. V. C. Francis	Very rarely seen among well-to-do. No slums in Los Angeles.
"	Geo. P. Laton	Greatest frequency of occurrence among negro population, next among the poor and least among the well-to-do.
"	J. R. Shuman	Rickets practically universal among negro population regardless of social condition. Is more prevalent among the poor in alien areas than among those living in more favourable surroundings. Believes condition exists more widely among well-to-do than is generally supposed.
Montreal, Canada.	E. Gaynon	No statistics, but believes that a great many cases could be found if a careful examination was made. Proportion of severe cases not great and are to be found mostly in the lower grade of population among all nationalities.
Saskatoon, Saskatchewan.	A. Wilson, Medical Health Officer	Rickets extremely rare in this city. There is no poverty; no slums.

There can be but little doubt that rickets is a disease which has greatly increased in the United States of America during the last two generations. Writing in 1893, Dr. J. H. Fruitnight,* of New York, states that twenty-five years previous to that date rachitis was a disease but rarely encountered in America. Owing, however, to the large influx of immigrants and the consequent development of overcrowding, analogous to what prevails in the teeming centres of the old world, impure and insufficient air, lack of ventilation, and want of proper exercise, have produced their effects on the nation, so that to-day it has become one of the most important and most common of the diseases of nutrition and growth among the humbler classes of the people.

It is to be regretted that no systematic survey of the United States has yet been made as to the relative frequency of the disease in its widely scattered and diverse environment. Several facts, however, seem clear. There is no doubt that rickets is an exceedingly common disease in the eastern portion of the United States, and is met with chiefly under the same conditions as in Europe, that is, in the great industrial centres and especially among people who are subjected to the evil environment associated with crowded slum dwellings. Chicago is a town of mushroom growth. In 1830 it was a village in the wilderness on the outskirts of civilisation. In little more than the space of a long life it has grown into an enormous city, with a population of 2,185,283, according to the census of 1910. In spite of the facts that the streets are well laid out and that its industries have developed great wealth, this unnatural growth has led to overcrowding and to the development of rickets to a formidable extent among the population.

The standard of living is higher in Chicago than it is in the great centres in Europe, and the climatic conditions are more favourable, and the disease though very common

* "The Treatment of Rachitis with the Lactophosphate of Lime," by J. Henry Fruitnight, "Trans. of the American Federation Society," Vol. V, 1893.

is less severe than it is in Europe. Indeed, taking North America generally, if the alien immigrant population and the negroes be excluded, the disease everywhere is of a comparatively mild variety. As one passes westwards it diminishes in frequency and severity, till in California only comparatively slight cases are seen. In Canada the disease is rare.

A striking feature of rickets in America is the universality of the disease among the negroes and the severity of the form with which they are attacked. All over the States the negro child is subject to the disease, so that even in Los Angeles, where the climate and general conditions are unfavourable to its development, Dr. J. R. Shuman reports that it is practically universal among the negro population. So much is this the case, that it is frequently suggested that there must be some racial predisposition to the disease. There is no reason to suppose that this is true. Every nation seems to be subject to rickets if it be exposed to the conditions necessary for its production. In South Africa the native, though civilised and although he has been associated with the white man for several centuries, has not developed the disease to any appreciable extent. As already noted, though the feeding among the African native races is probably less adequate in South Africa than in the United States, the conditions as regards overcrowding and defective housing hardly exist when contrasted with what pertain in the great cities of America.

In Jamaica rickets seems a rare disease among the coloured children. Here the conditions as regards feeding would all seem favourable to the early development of rickets. The children are nursed by the mothers for periods varying from six months to twelve months. At a very early date this is combined with starchy pap. As soon as they are weaned the diet consists of rice, bread, potato, yam, banana, casava, corn starch, etc. Most of these foods contain from sixty to seventy per cent. of starch in the dry state. The diet is poor in protein and fat and is rich in starch, the type of diet which in England and Europe is constantly blamed for

the production of rickets. In Kingston, the capital, the census of 1911 showed a population of 57,379, mostly negroes. In Jamaica generally only two per cent. of the population is white. Here, as elsewhere, the negro is improvident. It is difficult to get him to work more than four days a week, for so much labour supports him in comfort. Sixty per cent. of the births are illegitimate, and such a state of affairs, as is well known, is not conducive to the careful nurture of the child.* And yet rickets does not develop. Jamaica lies well within the tropics, between 17° 43' N. and 18° 32' N. and 76° 10' W. and 78° 20' W. The climate is one of the chief attractions of the island. Near the coast it is warm and humid, but that of the uplands, which occupies two-thirds of the island, is delightfully mild and equable.

In Kingston the climate is dry and healthy, the temperature ranging from 93° to 66° Fahr. The natives live in close huts in many cases, it is true, but the great secret of their immunity is found in the fact that the whole day is spent in the open air in warm sunshine and a benign atmosphere. Natives all over Africa and Asia tend to live in crowded and confined quarters in huts at night, but this has but little effect on the offspring, for the day begins with the sun and ends with its setting. The whole of the day is spent in the open, under the most favourable conditions as regards fresh air, free ventilation and sunshine, and where such circumstances prevail rickets cannot arise. The sleeping conditions are akin to what is found in the life of the wild animal. The mother with her young sleeps in close and confined quarters, in her burrow, but rickets never develops. Immediately, however, the young animal is removed from its natural habitat and is placed in confinement, and is deprived of sunshine in close and restricted quarters the disease tends to appear. Rickets remains the scourge in zoological gardens to-day, very much as it has been in the past; confinement, in the case of wild animals, is only a relative term.

* "Observations upon the Coloured Children of Jamaica, with especial reference to Rickets and to Mongolian Spots," by A. E. Vipond, *Archiv. of Pediatrics*, Vol. XXV, 1908, p. 503.

Deer confined in a park, no matter how commodious, are seldom in the same condition as the animal in its native state. The limbs, as a rule, are clumsy and the joints tend to be thickened. The coat is long, coarse, and shaggy, and the speed and power of sustained action in running are much impaired.

If the young infant from Jamaica were removed to one of the great cities of the United States, and lived under the same conditions that the negro population generally does, no matter what quality of food was given, rickets would certainly develop.

In speaking of rickets in Los Angeles, in California, Dr. Ramsay shrewdly remarks that the disease is present in a mild form in all classes of society, but that the racial factor and the distinction between rich and poor are not so important here as elsewhere. Slums are not common, and sunlight and fresh air are available for all and for rich and poor alike, so that variations in feeding and the amenities of life have not the same effect as they would have were the child brought up in damp and overcrowded surroundings, deprived of sunlight and fresh air, and exposed to a foul and vitiated atmosphere.

It is not, of course, implied that over any large area of the world's surface there is a total and complete absence of rickets. It is probable, when a complete survey is made of the world distribution of rickets, and the disease is systematically looked for, that it will be found in many parts where its presence was not previously suspected. Thus, in Australia the disease is of a very mild form, and, as has already been noted, but for the systematic inspection of school-children, actually looking for traces of the disease, the probability is that its presence would have been entirely overlooked. In the adult there would be no traces in the skeleton and but few in the teeth, for in the Australian-born hypoplasia seems to be quite uncommon, and the medical man in the course of general practice would not be likely to come in contact with the condition or to be struck by its presence.

It cannot, however, be argued that the disease even in a mild form is of no importance. It leads to much secondary disease ; it affects the growth of the whole body and especially of the delicate nervous system ; it leads to the development of enlarged tonsils and adenoids, and these are quite common conditions in Australia. The recognition of its presence is of prime importance to the public health authorities, in so far as it points to the direction in which the development of town conditions is becoming dysgenic in a new country, and in older European countries, to the steps which must be taken to free the young from the vicious circle which surrounds them in infancy at the most active period of growth, and at the time when they are most helpless and most susceptible to morbid influences.

The probability is that when carefully looked for traces of rickets will be discovered in every part of the world, but that is not likely to alter the fact that over a great portion of the globe's surface its presence is so infrequent, and the type of disease so slight, that it is of relatively no importance. Thus, it can be taken as a general statement that in Egypt, Algeria, Morocco, West and East Africa, Central Africa and South Africa, in other words, over the whole continent, and throughout India, China, and Japan, rickets is almost non-existent at the present time. The fact that Prof. Marfan * saw among a troupe of natives from Senegambia, who were being exhibited in Paris, a negro boy of three or four years of age who exhibited marked signs of rickets in the enlargement of the epiphyses, rachitic rosary, and knock knee, does not alter the general statement. From what is known of the development of rickets among negroes in the United States of America, it would not be a matter of surprise if, in the long reaches of the Senegal River, natives were found who lived under such conditions that rickets occasionally developed ; that would not alter the fact that within the tropics it is an extremely rare disease. In this case it may quite well be that the child suffered from acute rickets developed during the course of the voyage and the

* Marfan, " *Maladies des Os*," Paris, 1912.

sojourn in Europe. Nor does it alter the fact, which has an important bearing on the ætiology of the disease, that no matter what the conditions are as regards food and the feeding of the infant, rickets does not develop within these regions.

CHAPTER VI

Food in relation to the Geographical Distribution of Rickets

THE rise of the earlier civilisations has already been touched upon, and the explanation as to why these peoples advanced while others remained stationary has been referred to the fertility of the soil and to the genial climate allowing of the supply of a cheap and abundant national food. This led to an accumulation of wealth and to the development of a leisured and intellectual class, which was able to devote itself to extending the boundaries of knowledge. Unfortunately this ease of production was not, and never has been, entirely beneficial, for it led to a cheap labour market, an unequal distribution of wealth and power, and to the development of slave labour on a scale which the world has never seen equalled.

But not only have abundance of food supply, genial climate, and easy methods of distribution been important agents in the development of old civilisations in past ages. They remain to-day potent influences governing the health and physical and mental growth of nations. In the East the inhabitants adapted themselves with ease to the mild conditions imposed by beneficent physical features and a warm climate, but in the colder temperate zones the fruit of the soil, and still more, animal foods, were only acquired with difficulty and after long and strenuous toil. But the very stress brought to bear on these later civilisations, has had a most beneficial effect on the peoples so influenced, and has allowed of a rapid development, especially during the nineteenth and twentieth centuries, such as never could have taken place under the conditions affecting these older nations.

In still colder climates, north of the temperate zone, the struggle for the means of subsistence is so severe that it practically fills the life of the individual, and the Laplander

and the Eskimo have but little time and less inclination for the pursuit of purely intellectual progress. In tropical regions, as has already been noted, the food is mainly derived from the vegetable kingdom, with but little admixture of animal food, leading to a low protein and fat value and a considerable excess of carbohydrate. In temperate climates the diet is highly azotised, and is derived from both the animal and vegetable world, while in still colder climates the food is chiefly derived from animal sources with an abundant supply of fat. At one period of his existence man lived upon raw materials unaltered by the chemical and physical changes produced by cooking, but to-day food is everywhere used more or less cooked. Following the eating of raw materials there was a period when man cooked his food, but did not cultivate vegetables nor rear animals for food. During this period the vegetable world was the main source of supply, as this class of food was more easily obtained than the product of the chase. In modern times the bushman of South Africa and the aborigines of Australia had not advanced beyond this stage. No extracts of chemical substances such as sugar were made, and such natural products as honey were therefore greatly prized. This was followed by a stage in which man cultivated vegetables and reared animals for food.

Wheat was probably first cultivated in Mesopotamia, and bread making appears to have been known to the Chaldeans and Egyptians some 3,000 years before Christ. Rice was cultivated in China about the same period, and was introduced into India by the Aryan invasion. From India it passed into Europe with the army of Alexander the Great, in 334 B.C., and was carried from Europe to America in the fifteenth or sixteenth centuries. Maize, on the other hand, was first cultivated in America by the ancient inhabitants of Peru and Mexico, and was brought by the Spaniards to Europe, and its culture is now practically universal. Millet was cultivated from very ancient days in Africa and Asia, and even in the Stone Age its culture had extended into middle and southern Europe.

The development of tropical medicine within the present century has shown the immense importance of the study of the food factor in diseases affecting these regions. Beri-beri has now been demonstrated to be, what has been well termed, a deficiency disease affecting rice-eating peoples. In the tropics by far the most important article of diet is rice. It is calculated that it forms the staple food of some 400,000,000 Indians, Chinese, Japanese, and Malays.* It is a grain of comparatively poor nutrient value, being very deficient in nitrogenous substances, fats and salts, and exceedingly rich in starch. Taking the six chief grains—wheat, barley, rye, oats, maize, and rice, Parkes found that rice was the richest in starch and the poorest in azotised substances, fats and salts. According to Castellani, rice eating began in the over-population of Eastern Asia, leading to food difficulties and the great movements of peoples. Rulers invoked the aid of religion, and meat, which was scarce, was forbidden. To this day these religious principles are still in force, and the people avoid the use of animal food though the need for the enforcement of these enactments has largely passed away. Fats and oils among these people are not easily obtained, and ghee, for instance, in India, which is butter made from Indian buffalo milk, and clarified to resemble oil, is a luxury which is much prized, but which is not often within the reach of the common people. McCay† investigated the dietary of primitive peoples in Chota Nagpur, in Bengal, and gives the following estimate of their diet in food values. For purposes of comparison this has been placed alongside a "mean" dietary constructed from various sources.‡

	Daily diet of people in Chota Nagpur (McCay).	Daily diet for a man in ordinary work.
Proteins	80 grammes	122 grammes
Fats	50 "	100 "
Carbohydrates	500 "	332 "

* "Manual of Tropical Medicine," Castellani & Chalmers, London, 1919.

† McCay, D., *Indian Medical Gazette*, XLII, 1907, p. 370. "Scientific Memoirs," Govt. of India, Nos. 34, 37, and 48.

‡ "Food in Health and Disease," by J. Burney Yeo, London, 1893.

McCay has shown that where the protein standard of a tropical diet is very low, the physique, capacity for work, health and resistance against disease are all lowered, as in the rice-eating Bengali. What is true of Bengal is true of England, and on protein depend muscular power, physical endowment, powers of endurance and resistance to disease. Too little protein affects the growth of the Bengali boy, so that he grows up slender and defective in vigour and vitality. Loss of weight, anæmia, debility and prostration are exceedingly common and produce a high mortality, for young subjects bear starvation badly. Not infrequently the digestive functions are so degenerated from want of use that when a sufficiency of nutriment is given the system cannot utilise it. These badly nourished children suffer greatly from a cachectic condition associated with wasting and chronic diarrhoea, but rickets is not a common disease, as one would certainly expect it to be if the dietetic factor, and especially deficiency of fat, were the determining cause of rickets.

McCarrison has made some interesting observations on the people of the State of Hunza, situated in the extreme northernmost part of India.* They live a life of much hardship, owing partly to the scanty supply of food and partly to the severity of the winter in that part of the Himalayas. Their huts are of the most primitive kind. So limited is the food supply that McCarrison notes these people are not able to keep dogs. There is no dairy produce and the food consists of grains such as wheat, barley and maize, and an abundant supply of apricots. Yet with this limited dietary the people are long-lived and are but little subject to disease, and the children are well developed.

The inference McCarrison seeks to draw is that the diet contains the vitamins necessary for healthy growth. Such an explanation will not bear examination. Compare the lot of the infant and child brought up under these rigorous conditions with that of the child of the mill-worker in Oldham, in Lancashire, or of the collier in any of our

* "Studies in Deficiency Disease," by Robert McCarrison, London, 1921.

great coalfields. In variety and quantity of food the home child fares better than the native, for these workers live well and do not stint themselves as regards food. The general impression that the native child is nourished on an ample supply of wholesome breast milk does not, as has been shown in the case of the Indian native elsewhere, agree with the facts of the case. Prolonged lactation and the early addition of starchy foods are common faults in India and all over the East, and in the State of Hunza there is but little dairy produce to make good any deficiency. Yet rickets is rampant in Oldham and in the colliery districts, in spite of the fact that malt and cod-liver oil are freely administered to these ailing children, while in India the disease is absent.

The essential difference is in the environment. The native lives the life of a wild animal, in touch all day with the vivifying forces of nature, fresh air and sunlight, and engages in abundant exercise. The young infant is allowed to crawl at will in the open. The hut is a place of shelter but not of habitation. The child of the slum dweller at home lives for from eighteen months to two years in the vitiated atmosphere of a close and crowded room ; it is surrounded by mean streets and houses, in the midst of a great industrial centre, where all wholesome environment that makes for health is excluded.

Generally throughout India rice is the staple article of diet. Two varieties of rice are in use in the East : (1) Indian or country rice or paddy, usually described as unpolished ; (2) Burma or white rice, usually described as polished.

It has been established that it is to the removal of the germ and pericarp, which contain the essential necessary food factor, in the process of polishing of the grain, that the deficiency disease beri-beri is due. It must be remembered that a rice diet is exceedingly low in fat value, and that among these peoples the use of animal fats is greatly restricted. From the point of view of the geographical distribution of rickets, it is important to observe that among the enormous population of rice-eating peoples rickets is for

all practical purposes unknown. Such people subsist on a diet of low nutrient value, especially as regards protein and fat and even that not constantly ensured, for they live ever on the verge of starvation. Every known error in the rearing of the young infant which is usually blamed for the production of rickets in England is prevalent to an enormous extent. The mortality in infancy is high and the incidence of intestinal affections is very great, but rickets does not result. Such facts are wholly against the theory which has for long been accepted by most writers, that the dietetic factor is the cause of rickets.

For many years deficiency of fat has been blamed for the production of the disease on very slight evidence. Lately, it has been claimed that absence of fat-soluble A, or an accessory food factor associated with the fats, is the essential cause of rickets, while yet another school blames excess of food, and especially of carbohydrates, and a badly balanced diet. The consideration of the geographical distribution alone clearly proves that the food factor is not the cause of the disease. In so far as rickets is a disease of nutrition the quality and the quantity of the food undoubtedly have an important bearing on its progress, just as it has in tuberculosis or any other morbid condition associated with debility and wasting.

It is well known that a very large number of chemical bodies can be dissolved in the fluids of the body, producing varying effects, but it is a matter of common experience that certain substances are essential to the continuance of proper nutrition, and that the continued abstraction of these from the diet causes ill-health, and in the end death. These substances are oxygen, water, proteins, fats and carbohydrates, to which must be added certain mineral matters and salts. In the continued absence of any one of these constituents the body is unable to keep up normal tissue change, and especially to maintain healthy growth, and the prolonged absence of any one constituent from the food inevitably causes death. But certain conditions are known in which all these substances may have been supplied in

adequate quantity and yet nutrition becomes seriously impaired. In beri-beri there is an absence of a necessary food factor which, while not actually required for the building up of the cell in the same way as are the proteins, fats, and carbohydrates, is yet essential for the maintenance of health and even of the life of the individual. This substance, which is known as the anti-beri-beri or anti-neuritic factor, is probably identical with water-soluble B, although it has not yet been isolated in a pure condition. It is exceedingly widespread in its distribution, and has been found in all the natural foodstuffs examined at the Lister Institute, including wheat germ, wheat bran, rice germ, yeast, peas (dried), lentils, egg yolk, ox liver, beef muscle, and potatoes. It is found in varying proportions.

Another conspicuous example of a deficiency disease is found in Barlow's disease. In 1883, Sir Thomas Barlow published the results of an analysis of thirty-one cases of what he believed to be infantile scurvy. It will be seen later that the disease, infantile scurvy, was first described by Francis Glisson, in 1650, in his classical description of rickets. Not only did he describe the disease, but he defined the position of scurvy in relation to rickets, and maintained that infantile scurvy was an entirely independent condition, but that the two diseases were frequently associated together. In 1894, Barlow again discussed the relationship of infantile scurvy and rickets* and expressed his belief that these were cases of true scurvy due to inadequacy of "living" food reacting on a child with a rickety basis. The disease is of sudden onset, and may come on at any period after four months, but chiefly occurs between nine and eighteen months. The child is generally rickety, but is fairly well clothed so far as subcutaneous fat is concerned. From its common association with rickets it was known as scurvy-rickets. The symptoms and signs are well marked, consisting of anæmia, hæmorrhage from the gums, extensive sub-periosteal hæmorrhages and intense

* "The Bradshaw Lecture on Infantile Scurvy and its Relation to Rickets," by Thos. Barlow, *British Medical Journal*, Nov. 10th, 1894.

pain in the bones and joints, so that the child fears the slightest movement. The names of scurvy-rickets and acute rickets, which are applied to this disease, are unfortunate in so far as the condition is one of true scurvy, which may or may not occur in association with rickets. Barlow's disease, unlike rickets, is not a disease of the poor; indeed, it chiefly occurs among children who are well cared for, and whose state of nutrition is good so far as fat and weight are concerned. It does not occur in breast-fed children, differing again from rickets, which very frequently occurs in children suckled at the breast. It chiefly arises in infants of the better class who have been kept rigidly on one proprietary milk food, especially such as are mixed with water or with condensed milk, or who have been kept for long periods on condensed milk alone, or pasteurised or sterilised cow's milk. In using the term "living" food, Barlow adumbrated our present knowledge, which shows that the disease is due to the absence of an accessory food factor from the diet which is found in fresh meat and vegetables, and in natural unboiled milk and in fresh fruit juices. Barlow's disease and scurvy are now generally believed to be due to a deficiency of an accessory food factor named the anti-scorbutic factor. This appears to be a crystalline substance, capable of being destroyed at 120° C. or less. It is found in fresh potatoes, onions, cabbages, apples, lemons, limes and lime juice. It appears to be less stable than the anti-neuritic factor and is only found in the fresh condition of the vegetables and other foods. The condition is so distinctive that for many years now it has been a well recognised disease, but neither Barlow's disease nor ordinary scurvy is a common condition in this country. A physician may be in busy practice among the working class in the East end of London for several years and may never meet with a case of true scurvy. Probably, as has already been suggested, the universal use of the potato is largely responsible for the comparative immunity of the country from this disease at the present day.

In Europe there is only one nation which possesses a

cheap national food at all comparable with that possessed by the great rice-eating nations of Asia or the date-eating races of Arabia and Egypt. That nation is the Irish. In Ireland the labouring classes have for more than two hundred years been principally fed on potatoes, which were introduced into this country late in the sixteenth or early in the seventeenth century. The potato contains very little nitrogen and scarcely any fat. In former days the Irishman of the west country drank largely of buttermilk, but this has to a great extent been given up since the introduction of separated milk, and tea has been substituted. Bread is also more largely used than before. Formerly the only "meat" used, and that only occasionally, was imported American bacon, but there has been a tendency of late years to eat butcher's meat. The potato remains the staple article of diet. In the west of Ireland, and indeed over much the largest part of Ireland, rickets is conspicuously absent, while in the wealthy and prosperous industrial centre of Belfast, where the people are thrifty and provident and the food is both varied and wholesome, rickets is extremely prevalent. Among such a people as the west country Irish, had there been any truth in the theory that the cause of rickets was the absence of fat-soluble A or some accessory food factor associated with the fats, one would have expected to find it there.

The vitamin theory of disease is a fascinating one, and is one of those facile hypotheses which will explain anything. "The conception that vitamins provide the cells of the body with the capacity—one might almost say the will—to work, has this great merit, that it provides a working hypothesis on which to found our treatment," says McCarrison, in an important paper on the subject. "We should not," he continues, "restrict our vision of deficiency disease to such ailments as beri-beri, rickets, and scurvy—conditions so obvious and so severe that we cannot well overlook them—we should consider every state of ill-health from this point of view, so that we may be in a position to rectify nutritive errors and to provide the body cells with the requisite materials to enable them to fulfil their functions efficiently."

In the same paper difficulties are suggested. It is noted that in monkeys, where the protein intake is adequate and in proper proportion to carbohydrates and fats, the onset of symptoms due to lack of vitamins is much longer delayed and the loss of weight is not excessive, but where the deficiency of vitamins is associated with great excess of carbohydrates and still more with excess of fats, the onset of symptoms is rapid and the loss of weight is great. In other words, a properly balanced diet which contains a due and proper share of all the constituents necessary for the building up of the body is essential, not because it supplies vitamins which are missing, but because it supplies the necessary protein and fat—notably the protein—which tend to be deficient in the diet of the poor. It is a matter worthy of note that it is of little use giving malt and cod-liver oil to young children who are suffering from lack of food. For some years now malt and cod-liver oil have been supplied fairly freely in many of the London County schools to poorly fed children, with but very indifferent results. What is of much greater help is a fair supply of milk, and if this could be given twice daily in all schools, half a pint in the morning and half a pint in the afternoon, the greatest benefit would result. Fat-soluble A, the name given to the third factor, is also termed the growth factor. To the absence of this substance, or some substance with a similar distribution, the disease rickets is stated to be due. The probability is that this statement is entirely erroneous, and that while rickets is a disease of malnutrition, like most other diseases, and the quality and quantity of the food will naturally materially affect its progress, that there are no conditions of diet which will actually originate it. Rickets has a superficial resemblance to scurvy, but has absolutely no causal relationship with it, nor can it rightly be placed in the same class as a deficiency disease.

Drummond* states that fat-soluble A is synthesised by plant life and is present in most green leaves and in the embryos of certain cereals. Such foodstuffs contain the

* "Some Aspects of Infant Feeding," by J. C. Drummond, *Lancet*, Vol. II, 1918, p. 482.

primary sources of the factor for the animal organism, which apparently does not possess the power to synthesise it. In the embryos of seeds this substance occurs in loose combination with protein, but when liberated, as it is during digestion, it shows similar solubilities to the fats and lipoids and accompanies these substances during absorption. The exact part this factor plays in the metabolism of the body is, Drummond states, quite unknown, but it is believed that a liberal supply is necessary for the growing animal. When formed in excess the factor is stored as depot fat or in association with it. It is stated that young animals, when deprived of this factor in their diet, do not show immediate signs of disease, because the organism draws on its store contained in this reserve supply. In the new-born infant, as will be seen later, this is an entirely erroneous observation. Fat is a tissue which is conspicuously absent in the new-born—indeed the deposit of fat in the subcutaneous tissue in large amount and the signs of rickets frequently appear in the infant at the same time, some six or nine months after birth.

The following table shows the distribution of these accessory food factors in various foodstuffs:—

Foodstuff.	Fat-soluble A.	Water-soluble B or anti-beri-beri factor.	Water-soluble C or anti-neuritic factor.
Milk	+ +	+ +	+
Butter	+ + +	—	—
Cream	+ +	+	+ ?
Separated Milk ...	—	+ +	+
Egg yolk	+ + +	+	?
Egg white	—	+	?
Beef fat	+ +	—	—
Lard... ..	—	—	—
Margarine	—	—	—
Vegetable oils ...	—	—	—
Cod-liver oil ...	+ + +	—	—
Wheat (whole grain)	+	+ +	—
Rice (polished) ...	—	—	—
White bread	—	—	—
Wholemeal bread ...	+	+ +	—
Cabbage (fresh) ...	+ +	+	+ + +
Spinach	+ +	+	+ + +
Oranges	—	—	+ + +
Onions, Apples ...	?	—	+ + +
Lemon juice	—	—	+ + +

+ = rough content value ; — = absence.

Particularly noteworthy is the statement that lard is of no efficacy as regards the supply of the growth factor. This is in conflict with all clinical experience. The administration of bacon fat to the young child has been found one of the most efficient and most digestible methods of introducing fats. For centuries in Europe, throughout the Middle Ages, the pig was almost the sole source of meat used by the common people.

In experiments on animals no mention is made, as a rule, of the manner of supplying fats in the diet. The method of administration of fats is clinically of the first importance in infant welfare centres. It must be remembered that the milk of the mother is a most perfect emulsion and one which does not readily separate out. Underfed infants in welfare centres do not digest fat well unless it is very perfectly emulsified, and the great success of many of the patent preparations is largely due to the very perfect degree of emulsion which has been produced by mechanical means. Emulsification by hand by means of tragacanth is not nearly so efficient. No record of the value of the various fats in the metabolism is of much use unless the method of administration is given in careful detail.

The statement that certain diseases are due to the absence of important accessory food factors, other than the ordinary constituents of the food used in the building up of the cell, is now passed beyond the stage of mere theory and is accepted by nearly all as the actual cause of scurvy and beri-beri. But extravagant claims have been made as a result of these discoveries, and it has been suggested that practically all disease has its origin in this one factor. Suggestions have even been made to hasten forward legislation for the regulation of foodstuffs on grounds which must be considered wholly insufficient to warrant any such drastic measures. Extravagant dietaries are prescribed for children on the strength of ill-considered newspaper articles, and raw vegetables, raw salads and raw fruits are frequently given to children to the exclusion of meat and more easily

assimilable mixed diets, not with the idea of giving to the body the constituents necessary for its nutrition and growth, but to supply hypothetical vitamins.

Nature is a tolerant mother and children thrive under food conditions which would often seem to be attended with the gravest risk. The best results are not obtained by these eccentric diets. Experience has shown that it is well, especially in the case of children, to throw the net as widely as possible and to include all the varied articles of diet, both animal and vegetable, for which mankind is adapted. Meat and fish are from a very early date essential constituents of the dietary if the best results as regards growth and physical and mental development are to be obtained. As has already been pointed out, in tropical countries where the diet is frequently greatly restricted to one article, such as rice, the danger of the onset of deficiency disease is a real one, but it has yet to be shown that with the immensely varied diet of even the poorest in England, that a deficiency of vitamins is a factor of importance in the production of disease.

In the case of rickets, the evidence supporting the claim that it is a deficiency disease due to diets, which are unbalanced in that they contain too little of those substances rich in a so-called anti-rachitic factor, which is either identical with fat-soluble A, or has a similar distribution, and too much of those substances deficient in this respect,* is still entirely wanting, and there are many facts, as will be seen in discussing the ætiology of the disease, which tend to disprove any such connection. According to this view, it will be noted that an unbalanced diet is one deficient in vitamins, differing from the old accepted view of an unbalanced diet as one in which the proportion of the great food factors, proteins, carbohydrates, fats, water, and salts, is badly balanced and insufficient to support the demands of the normal metabolism and growth of the body.

* "Report on the Present State of Knowledge concerning Accessory Food Factors," Medical Research Committee, London, 1919, p. 91.

The amount of these hypothetical substances required for the proper growth of the body is apparently extremely small, and even experimentally, and with the most complete laboratory methods it is extremely difficult to exclude them from artificial diets.* Again, they are exceedingly widely spread throughout the vegetable and animal kingdoms, and it is difficult to believe that in the ordinary child's diet, where the complaint is usually made that the child eats anything and everything from the table, that the loss of a vitamin or vitamins is a common existing cause of disease in this country. It is not of course claimed that the diet for the child in England, and still less in Europe generally, is adequate or that ignorance in the rearing of the young infant does not exist. But it might reasonably be expected that such diseases would be prevalent among those nations where the diets were restricted mainly to one staple article, such as rice, and where such ignorance was much more common than at home. When it is claimed that deficiency of fat, or of some active principle commonly associated with fat, is the actual exciting cause of rickets, it is difficult to reconcile this with the almost complete absence of the disease from rice-eating nations, who constitute the majority of the people on the globe's surface, and from such a nation as the Irish, who live largely on potatoes, where the fat content of the diet is conspicuously low.

That many bodies exist in the milk of the mother, apart from the constituents actually necessary for the building up of the tissues of the child and for the supply of energy, has long been considered probable. It is difficult to explain otherwise the comparative immunity which the breast-fed child enjoys from the ordinary zymotic diseases, than by the action of some ferment conveyed in the milk conferring on the child an immunity which the mother herself has acquired.

Like all who claim that the food factor is the essential cause of rickets, McCarrison notes that environment plays an important part, want of fresh air and sunlight hastening

* *Loc. cit.*, p. 13.

that functional depression of cells initiated by the vitamin deficiency. In this factor of faulty environment lies not only an important part but the essential agent in the production of rickets, without which the disease cannot be produced. It is the one constant common factor which explains the history of its development as a national disease, the age at which it occurs in the individual child and its very definite geographical distribution. As will be seen more fully later, the constant conditions which are present when rickets is prevalent are : (1) the breathing of a vitiated atmosphere in close and confined dwellings ; (2) the exclusion of sunlight ; (3) the lack of opportunity of exercise ; (4) damp climates and long winters, notably in the colder northern temperate zones.

Where such conditions prevail rickets will develop in spite of the best of breast feeding. These evil factors produce their chief effect in the young infant immediately it begins to lead a separate existence after birth, at a time when fresh air and free oxygenation of the blood are most essential. Under such circumstances nature rapidly produces the lymphatic rachitic child, with shallow, quick breathing, holding in strict reserve all its activities, so that no undue demands are made for fresh air and sunshine and abundant movement, which are all so essential to the proper growth and development of the young infant.

Among Asiatic peoples there is an ignorance of the ordinary principles of healthy infant feeding, as we understand them, which exceeds anything which can be found in Europe. Lactation is prolonged and the addition of starchy pap at any early period to the diet is the rule. Gastro-intestinal infections are intractable and severe and produce a high mortality ; marasmus and deaths from starvation are quite common, but for all practical purposes rickets is absent. On the other hand, rickets is almost wholly confined to a comparatively narrow belt running across America and Europe—a zone which is the wealthiest in the world and into which all the richest and choicest products of the earth are poured in their natural state. To-day, the child

and the wife of the collier live on a dietary much greater in food value and more extensive in variety than did even the wealthy of say three hundred or four hundred years ago. Notwithstanding, rickets is rampant among the colliers' children to-day, while in these older times it was hardly known, if the evidence from the examination of the teeth, jaws and skeletons of ancient burials is to be believed.

There is no true race degeneracy, but, at the same time, the concentration of enormous populations in large towns in defective dwellings in slum areas, has led to the development of aberrations and modifications of growth which have a wide effect on the community, producing much secondary disease and preventing the attainment of the normal standard both as regards physical and mental development, which might reasonably be expected if better conditions prevailed.

CHAPTER VII

The Early Signs and Symptoms of Rickets

SIR WILLIAM JENNER, in his well known lectures on rickets, delivered at the Hospital for Sick Children, Great Ormond Street, in December, 1859, prefaced his remarks by describing in detail four great diathetic diseases of children, viz., rickets, tuberculosis, scrofulosis and syphilis.* By the term diathesis, at that time and up to comparatively recent years, was meant a constitutional predisposition towards certain diseases affecting the individual from birth or from an early period of post-natal existence. Rickets, tuberculosis, and scrofulosis, were held at that time to be diseases of malnutrition, but, as Jenner pointed out, this term is vague, and all diseased action by which unhealthy structure is formed in the place of healthy may be called malnutrition. It is in this sense that rickets is a disease of malnutrition, for while it is most commonly associated with a dietary, deficient in quantity and defective in quality, it is frequently found where no exception can be taken to the feeding in either of these respects. Again, it is commonly seen where the fault in the feeding lies in the direction of excess, both as regards variety and quantity. In any case, wasting is not an essential characteristic of rickets. On the contrary, there is a conservation of the processes of metabolism, and the rachitic child on an insufficient and inadequate diet, is frequently unduly fat, and is pale and flabby.

All these diathetic conditions, Jenner taught, tended to end in actual diseases, which were apt to be exceedingly widespread and to produce large deviations from the healthy

* "Clinical Lectures and Essays on Rickets, Tuberculosis, Abdominal Tumours and Other Subjects," by Sir William Jenner, Bart., G.C.B., London, 1895.

structure in certain particular organs and tissues. With the discovery of the tubercle bacillus as the cause of tuberculosis and the spirochæte as the cause of syphilis, the consideration of the soil as a factor in producing disease for a time fell into the background, and such terms as scrofula and struma were but seldom used. When Jenner used the term diathesis it is clear that he did not necessarily mean a congenital or inherited tendency, for, while speaking of the rachitic diathesis, he describes it as part of the process of the actual disease and states, "I have never seen congenital rickets," and again, "I know of no facts to prove that rickets is hereditary." Tubercle, he considers, may be hereditary, while the syphilitic diathesis is usually so.

The term scrofulosis, as used by Jenner, is very suggestive of a stage in the development of the rachitic state. If this be excluded, there are three morbid conditions left which show great resemblance, in that they frequently affect the very young child at the period of greatest growth, and that the chief pathological changes tend to occur in the structures and tissues in which growth is most active. Rickets is not necessarily a true diathetic disease in the sense that the child is born with a constitution which tends to develop some definite form of disease. Neither can congenital syphilis be rightly spoken of as a diathesis in so far as there is an actual infection and not a mere tendency to invasion.

In rickets, all children if exposed to certain conditions develop the disease, and racial characteristics seem to have but little influence. I can find no confirmation in practice for the generally expressed belief that Jews enjoy an immunity from the disease. Rickets is the result of certain definite causes, without which the condition cannot be produced, and these causes are exceedingly constant and widespread, affecting large sections of the community.

In making statistics in social work on the causes which produce certain morbid processes, the greatest caution is needed in drawing the inference that because the condition affecting the child exists in the parent it is therefore hereditary. When the causes are widely spread, it is

exceedingly difficult to discriminate between the part which heredity plays and that which truly belongs to environment. In tuberculosis, however, certain children, certain families, and certain races, seem more liable to infection than others when exposed to similar conditions. There is still much truth in the old description of the tubercular diathesis as a clinical picture. In every children's hospital two types of patient are well known.

The tuberculous subject is frequently a charming child, with a tall thin figure, straight and slender limbs, and a delicate and transparent skin. The ends of the long bones are very small and the layer of cartilage between the diaphysis and the epiphysis is thin and regular. The complexion is clear, the eyes are bright, the eyelashes long, and the hair glossy. The child is forward and clever; it cuts its teeth early and talks and walks at an early period. Not only are the teeth cut at the usual period but the enamel is generally well formed and the teeth are but little liable to decay. It is surprising how frequently in the tuberculous subject the teeth are large and well shaped and very firmly set in the jaw. Clinically, it is difficult to believe that such a constitution is the direct result of the actual invasion of the child's system by the tubercle bacillus. It is often seen in children who are brought up with the greatest care as regards feeding and general nourishment. While such a child seems to fall an easy prey to the tubercle bacillus, it is undoubtedly true that if the actual environment remains good and the child is not unduly weakened by acute disease, it may grow into a healthy adult without ever showing signs of any actual tubercular focus and may outgrow the tendency.

The rachitic child, on the other hand, tends to look dull and heavy. The head is square and the skin is coarse and pasty and is frequently harsh and dry. The hair is often scanty. Knock knee and bowing outwards of the legs are common, and the ends of the long bones are markedly thickened in the neighbourhood of the growing cartilage. Walking and speech are delayed and the child is late in cutting its teeth. As will be seen in detail later, the teeth

of the rachitic child are stunted and the enamel is often very imperfectly laid down. The tendency to early decay of the teeth is one of the conspicuous features of rickets. The child has an old-fashioned air which gives an appearance of precocity, quite different from the bright, alert look of the tubercular subject.

There is a general impression that the rickety child is precocious, but in reality it is essentially a backward child. In considering the development of one thousand children, examined in schools in the East end of London, it was found that of eight hundred who showed signs of rickets:—

	Per cent.	Per cent.
Walking or speech was delayed in ...	48·0	
Both being delayed in ...	...	29·0
Walking alone delayed in ...	...	12·5
Speech alone delayed in ...	...	6·5
Neither speech nor walking delayed in ...	52·0	

The period constituting delay is taken as eighteen months, so that those cases of delayed development did not walk or speak till after the age of eighteen months.* To-day rickets remains the most widely spread disease in London among children. Tuberculosis is also common in young children, but it is of a different variety from the adult form, pulmonary tuberculosis being but rarely seen, while tubercle of the glands, bones and joints is frequently present.

Rickets is a general disease affecting the nutrition of the whole body. It results in retarded growth and development. The teeth are cut late and the child is slow in walking and in speaking. The ossification of the bones is delayed and perverted, and the bones consequently become soft and the muscles and ligaments which support the joints become wasted and relaxed. In many cases there are profound alterations in the central nervous system and in the lymphatic glands, and to a less extent in the liver and spleen. The disease is essentially one of the first few years of the child's life and more particularly of the first two years.

One or two landmarks in the growth of the infant during this time may be shortly referred to. At birth the average

* "On the Incidence of Rickets in School-children," by J. Lawson Dick, *School Hygiene*, May, 1916.

child weighs seven and a half pounds. At five months the weight should be fourteen pounds, and at eighteen months twenty-one pounds. The relatively enormous growth of the brain which takes place during the first few years of the child's life is a factor of the greatest importance in studying the results of any nutritional defect at this period. Any state of impaired nutrition which acts continuously at this early period will have far-reaching effects on the development and structure of the central nervous system. The disease is partially recovered from, but there is apt to be a permanent arrest or perversion of the growth and development of the brain itself. If the weight of the adult brain be taken as 100, the brain of the child may be represented at various ages thus :—

	At birth,	weight of brain	=	30 per cent.
At the end of the 1st year	"	"	=	50 "
"	"	4th "	"	= 75 "
"	"	14th "	"	= 92 "
"	"	19th "	"	= 100 "

Now, as Sir Arthur Keith has pointed out, there is a mechanism which controls the growth of the skull so that it adapts itself to the needs of the rapidly growing brain. The rapid increase in the size and weight of the brain during the first few years is reflected in an equally rapid increase in the circumference of the child's skull over the same period. This rapid growth may be expressed at various periods thus :—

Circumference of the head at birth	=	13 inches
"	"	nine months = 17 "
"	"	one year = 18 "
"	"	five years = 20 "

It will be noted that during the first year there is a very large increase in the cranial growth, viz., five inches, while in the four succeeding years there is a further growth of two inches, and there is a comparatively slight enlargement afterwards up to adult life. The first year of life is the time of all others when the whole environment of the child should make for health, while in practice it is the period when all the evils of a pernicious environment are concen-

trated on the young infant, with lasting damage to the individual and to the community which is subjected to such an environment.

In the East end of London the feeding of the young infant at this period is, on the whole, very fair, much better indeed than is generally supposed, but the conditions arising as the result of overcrowding of families of four, five and six individuals in one, two or three rooms, with the consequent loss of fresh air and sunlight, which are so essential for all vital processes, and the want of the opportunity for exercise and proper cleanliness, are all brought to bear in full force on the young infant up to the end of the second year. By that time much irreparable damage has been done.

To allow of moulding of the child's head during birth and of free expansion of the brain afterwards, the skull has at first a fair amount of mobility between its component and adjacent parts. There are six fontanelles in the child's skull at birth. The anterior fontanelle lies between the antero-superior angles of the parietal bones and the superior angles of the ununited halves of the frontal bone ; the posterior is situated between the postero-superior angles of the parietal bones and the superior angle of the occipital bone, while the lateral fontanelles, two on each side, are irregular in shape and are situated at the inferior angles of the parietal bones. The lateral and posterior fontanelles close during the first few months of infancy. The closure of the anterior fontanelle forms an important clinical landmark. It closes between the eighteenth and the twenty-fourth month, and any delay beyond that period should be looked upon as abnormal. In rickets it may remain open till the third or fourth year or even to the sixth year.

A systolic bruit, the so-called rachitic souffle, is frequently to be heard in the region of the open anterior fontanelle, and it was at one time claimed that this was a sign pathognomonic of rickets. It is, however, found in many conditions besides rickets and may occur in the normal child. Anæmic states may produce the souffle and it is also found in hydrocephalus.

At from three to four months the child should be able to hold up the head, and at nine months the development of the spinal muscles and of the body muscles generally allow of the child sitting up, while at from twelve to eighteen months the child should begin to walk. Owing to the profound debility usually present in rickets, these muscular efforts are commonly much delayed.

In early infancy syphilis and rickets have many characteristics in common. Both are peculiar in that their effects are indefinitely prolonged, unlike most diseases which have a period of invasion, acute stage, and convalescence, within a short space of time. Both syphilis and rickets tend to run on for years, and the system is profoundly affected at its period of most rapid growth. In both a widespread process of rebuilding or reconstruction takes place, which leaves stigmata recognisable especially in the skeleton, skull and teeth. Both diseases show a predilection for certain sites. Thus, both tend to affect the enamel of the permanent teeth, and especially that part of the enamel laid down in the first few months of the infant's life. In syphilis, the central incisors and the first molars of the permanent dentition tend to be contracted and peg-shaped, while the enamel of the incisors shows a hypoplastic condition resulting in the characteristic notch of Hutchinson's teeth. In rickets, the central and lateral incisors, the tip of the canines and the crowns of the first molars are frequently affected with hypoplasia. Again, syphilis and rickets tend to affect the centres where active ossification is proceeding. Thus, in both there is a tendency to bossing of the skull, and both frequently affect the sites of greatest growth at the ends of the long bones, though this is peculiarly characteristic of rickets.

There are, however, essential differences. Congenital syphilis is due to the infection of the ovum by the spirochæta pallida. Rickets is a disease which is not congenital, and up to the present no specific micro-organism has been found. Syphilis is a disease commonly seen at infant clinics, such as the various child welfare centres now

springing up all over the country. It is rarely noticed in children of school age. It produces a profound toxæmia, so that both the ante-natal and post-natal mortality is very large, and comparatively few survive to adult life. Rickets, on the other hand, tends to end in recovery, and while commonly seen in baby centres, the stigmata produced by the disease are still exceedingly common in later years among school-children.

In any primary school of our larger industrial towns valuable statistics as regards rickets could be found if a careful investigation were made of all the children, but it would be useless to attempt to collect statistics as regards syphilis from any one school by means of an ordinary inspection; the number of cases would be too small. So common is rickets in the slum areas of our large towns, that it may be broadly stated, that practically all children living under these conditions have to struggle through a rickety phase of their existence, when the whole tide of growth is profoundly disturbed, producing permanent damage to the body tissues and skeleton, and especially to the sensitive tissues of the brain and nervous system.

Rickets and syphilis are distinct pathological entities. Parrot's theory that rickets is simply a manifestation of syphilis cannot be accepted, but it is probable that in certain cases syphilis is a factor predisposing to the onset of rickets. So closely do the two diseases resemble each other in their effects, that it is frequently difficult to tell to which disease a certain morbid process owes its origin. This is notably the case with cranio-tabes and enlargement of the spleen.

Elsässer, in "Der Weiche Hinterkopf," published in Stuttgart in 1843, first described the condition of cranio-tabes. It is a very characteristic defect found in young infants, usually developing before the sixth month. Softened areas appear in the cranial bones, in the vicinity of the lambdoidal suture, especially in the parietal and occipital bones. The squamous portion of the temporal bone is not infrequently affected. Much more rarely they appear in the

anterior part of the parietal bones, still more rarely in the frontal bones in the region of the coronary suture.

In the examination of 100 cases of cranio-tabes, Carpenter found the bones of the skull affected in the following order of frequency: parietal bones alone affected, 58 per cent.; parietals affected with squamous-temporal or occipital or both, 35 per cent.; occipital bones alone affected, 2 per cent. The large number of cases in which the parietal bones are affected is noteworthy, while the occipital bone is affected much less frequently than is generally supposed. The softened areas can best be felt by holding the infant's head between the palms of the hands, so that the index and middle fingers fall over the occipital bone, and palpate the skull for the areas of thinning in the bone, which often give way under the pressure of the finger, producing the characteristic feeling of parchment-like crackling. More rarely does the condition develop after the sixth month. According to Jacobi, it may be found in forty per cent. of cases of rickets if carefully looked for. To find the condition in this large number of children the skull must be palpated with the greatest care and skill, and very minute areas of softening must be noted.

These softened areas may be due to thinning of the bone to a parchment-like texture, or there may be actual openings in the bony skull, where only the pericranium and dura are left to cover in the space, without the intervention of bony tissue. These areas vary in size from one line to a half or three quarters of an inch in diameter. They may be rounded or oval in shape and are frequently irregular. On the internal surface of the cranium the borders of these areas are usually formed by a heaping up of the surrounding bone, which shelves rapidly down to the gap. It is as if the pulp of the finger had been kept continuously maintaining a gentle pressure on the young bone, preventing the process of ossification occurring under the finger and allowing an accumulation of bone to take place round the margin not directly under pressure. These heaped-up edges of bone are frequently very vascular. In the distribution of cranio-

tabes there is usually an approach to symmetry, though the defect may be more marked on one side than on the other. At times there is no opening but merely a thinning of the bone producing a depression; not infrequently at the bottom of this depression there is a small opening.

Cranio-tabes is not pathognomonic of any one diseased condition. Sometimes it seems to be a simple delay in the process of ossification within normal limits. Elsässer believed that the condition was essentially rickety in its origin. Other observers, however, have pointed out that syphilis is very common in cranio-tabes. Thus, in one hundred cases of cranio-tabes, Barlow* found undoubted syphilis present in forty-seven, and concludes that the existence of well marked cranio-tabes is strong ground for suspecting a syphilitic taint. Dealing with a similar number of cases, Carpenter† found that in seventy-four per cent. the diagnosis of syphilis was certain. The fact that it is a very early sign, usually appearing before the sixth month and tending towards spontaneous cure, has been held to support the view that syphilis is the exciting cause, for it is at this early period that syphilis is especially operative. After the sixth month rickets is much the more common condition and tends to develop, while cranio-tabes at this period tends towards recovery, so that Cohn,‡ in an examination of 1,164 children found that 34·6 per cent. had cranio-tabes and that this percentage was higher under three months. Wieland showed that softening of the cranial bones is present in about twenty per cent. of infants at the time of birth. This congenital softening, according to Wieland,§ has none of the histological features of true rickets.

It may be concluded that cranio-tabes is pathognomonic

* "Relationship of Cranio-tabes to Rickets and Congenital Syphilis," by Dr. David B. Lees and Dr. Thomas Barlow, "Transactions of Pathological Society of London," Vol. XXXII, 1881.

† "Cranio-tabes in Young Children. A Clinical Enquiry into its Origin, illustrated by 100 Cases," by George Carpenter, "St. Thomas's Hospital Reports," Vol. XIX, 1889.

‡ "Zur Pathologie der Rachitis," von Dr. Michael Cohn, "Jahrbuch für Kinderheilkunde," Band XXXVII, p. 189.

§ Wieland. "Ergebnisse der inneren Medizin und Kinderheilkunde," Band VI, p. 64.

of neither rickets nor syphilis ; it may occur in both and probably as a direct consequence of either disease. By many it is held to appear in healthy children. (Friedenleben, Comby.) Generally, however, it is encountered in badly nourished infants. In most of our pathological museums are specimens where the disease is widely spread along all the sutures extending to the anterior part of the parietal and to the frontal bones. In these severer cases the tendency to a wide symmetrical distribution is usually marked and is very suggestive of congenital syphilis. When the condition occurs early, say at or before the third month, and is well marked, the probability is that the disease is due to a syphilitic taint. Frequently the condition is associated with undue and continued pressure. Thus, it is commonly associated with the deformity of the head known as plagiocephaly.

Plagiocephaly is a condition in which there is a deformity of the skull produced by sustained pressure, which may be due to a faulty decubitus either during intra-uterine life or in the first few months after birth. One side of the frontal region, as a rule, is flattened, and one prominent, corresponding with a flattened and a prominent parieto-occipital region posteriorly. The head is obliquely oval, and the long antero-posterior axis is deviated to one or other side, corresponding with the prominent frontal and occipito-parietal regions. It has been stated to be essentially the deformation of the degenerate. Such a statement requires much modification. Asymmetry of the head is so common as to be the rule, and in so far as plagiocephaly is a condition due to physical pressure applied to the cranial bones at the period when the cranial bones are soft, and the growth of the bone is exceedingly rapid, the causes are very varied and may be far removed from degeneracy. When the condition is of intra-uterine origin, it may be associated with large size of the head in a perfectly healthy large child without other abnormality, or it may be due to the expansion of the head following hydrocephalus. In either case it may be a useful deformation, favouring the passage during labour

of a head which would otherwise be disproportioned to the pelvic canal through which it had to pass. Or again, it may occur when the head is of normal size, owing to undue pressure of the promontory in a contracted pelvis.

In the commonest form, when the child lies *in utero* in the ordinary left occipito-anterior position, the left frontal region is flattened, corresponding to a flattened right occipito-parietal region. In this case the pinna of right ear is prominent and stands away from the head, while the left ear is closely applied. It is as if two hands had been placed over these two regions, the left frontal and the right occipito-parietal regions, compressing this oblique diameter of the head till in its growth a corresponding bulging takes place in the other oblique diameter, that is, over the right frontal and the left occipito-parietal regions. When congenital the deformation of the skull is not due to rickets in the child, though it may be due to the pressure of the promontory, which may take place as the result of rachitic deformity of the maternal pelvis.

Plagiocephaly may also be due to the decubitus of the child after birth, when it is usually associated with rickets. If the child be delicate and weakly, and especially if the bones of the skull are softened by the early onset of the rachitic state, the head, from the pressure on the pillow as it lies in the cot, may become deformed. Usually, the child is placed on the right side, and again, the commonest deformity is flattening of the right parieto-occipital and left frontal regions. Cranio-tabes is frequently associated with this condition, and while it usually affects both sides, it predominates as a rule on the side of the parieto-occipital depression. Cranio-tabes is frequently congenital, and, as Parrot pointed out, when this is the case it tends more frequently to affect the anterior part of the skull round the anterior fontanelle and along the line of the sagittal suture. Assuming that pressure due to the weight or rapid growth of the brain, associated with undue softening of the bones, are the usual causes of cranio-tabes, it can readily be understood that in the ordinary head presentation of the child the front part of the skull is

likely to be affected as well as the posterior part, while in the child after birth the posterior part is likely to show the more marked changes.

The depressions and elevations seen on the inner aspect of the skull in cranio-tabes represent the exact mould of the convolutions and sulci of the brain. The pressure of the rapidly growing brain and the counterbalancing pressure on the outside, in the one case of the soft parts of the pelvis, and in the other of the pillow as the child lies in the cradle, determine the exact spot where the delay in ossification or the thinning of the bone takes place. In the congenital form, as already noted, the process may be a simple delay in the ossification due to pressure ; after birth many of the cases where softening, and later re-absorption of newly deposited bone occur, are the result of rickets, and are directly due to the same cause, viz., pressure.

Elsässer attached great importance to this condition as a cause of convulsions, frequently ending in the death of the child. It has been blamed for producing laryngeal spasm, and Kassowitz believed that it was an active factor in producing tetany. Pressure on the softened areas is, however, well borne, and the danger of compression of the head is probably purely imaginary. As a rule, after the sixth or eighth month, cranio-tabes ends in rapid recovery, with the renewal of ossification.

CHAPTER VIII

The Early Signs and Symptoms of Rickets

(Continued)

IN describing rickets some general statements are commonly made which have been originally expressed by some authority and, as a result of constant reiteration, have come to be looked upon as established facts without any critical examination into their accuracy. Thus, it is commonly stated that rickets is not usually found in children nursed on the breast unless lactation is unduly prolonged. Now it is true that artificial feeding is a serious handicap to a child, and is likely to predispose to rickets, but it is no less true, that given certain conditions—the conditions which prevail in slum dwellings in our larger industrial towns—rickets will develop with equal frequency in the breast-fed babies of healthy mothers as in those who are artificially fed. In considering the ætiology of rickets this is an important matter to realise. The only advantage that the breast child has, is, that it will probably suffer less severely than the child brought up under similar unhygienic conditions, but artificially fed.

Another common statement is that deficiency of fat or excess of carbohydrate is an important or even the essential factor in producing rickets. This requires very careful examination. Fat is, of course, an important item in the infant's diet, but it is to be noted that in a large class of patient, where the feeding is unexceptionable in this respect and where the fat nutrition is excellent, rickets is frequently well marked.

Wasting is by no means necessarily associated with rickets. The state of nutrition of the child and its digestion may be exceedingly good to all outward appearance. It frequently has a good colour and is very plump and fat,

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though even then it may be noted that the child is somewhat dull and lethargic, and that the muscular system is unduly soft and flabby. Frequently such children are brought to the physician for the first time because they have not cut any teeth by the tenth or twelfth month.

A badly balanced diet, in which there is an excess of carbohydrate and a deficiency of protein and fat, is a very common defect in the feeding of young children, but in itself such a diet does not produce rickets. All the conditions of a badly balanced diet are, as has been shown, present to an extreme degree all over the East, prolonged lactation frequently extending to two or three years, while the early admixture of starchy foods with the breast feeding is the rule. Such conditions are constantly cited as specially pernicious and likely to produce rickets, and yet in China and India, where these factors prevail to a degree altogether unknown in Europe, rickets is for all practical purposes a negligible quantity.

It is commonly stated that the first stage of rickets is marked by the signs of gastro-intestinal irritation. There is very little evidence to support such a statement. There is no doubt that the nutrition of the child fails and there is an arrest, in the majority of cases, of the normal process of growth; obviously there is marked impairment of the normal metabolism. But in rickets the signs of gastro-intestinal irritation in its earliest stages are by no means common. Neither vomiting nor diarrhoea is characteristic of this stage of the disease. Both symptoms are absent in the great majority of cases. Von Hanseemann* rightly pointed out that almost all children born during the late part of the year, and dying during the following spring, show evidence of rickets, though these are the months when gastro-enteritis is not prevalent, while those born in spring (April and May), and dying in the autumn, are free from rickets, though they have passed through the period when gastro-enteritis is exceedingly common, and, in itself, causes many deaths.

* "Ueber die Rachitis als Volkskrankheit," *Berlin. Klin. Woch.* No. 9, 1906.

Rickets is essentially a chronic disease and is very insidious in its onset. About the third or fourth month the child is found not to be thriving. It becomes less lively, and at five or six months, instead of rejoicing in activity it prefers to be quiet and motionless. The skin, in place of being clear and healthy, tends to become somewhat dull and pasty. Profuse sweats are apt to break out over the head and neck and the upper part of the chest. This occurs most markedly during sleep, and whether the infant falls asleep at night or during the day. Very characteristic, at a slightly more advanced age, is the action of the child in tossing off the bed clothes, the body, feet and hands being hot and dry, while the head and neck are bathed in perspiration, which saturates the pillow. The skin of the forehead is often thin and white and the distended veins show very markedly. Sudamina and miliaria are apt to appear on the skin as the result of the excessive perspiration.

The jugular veins are full and the carotids are seen to throb markedly—a point on which Glisson laid much stress. Insomnia and nervous irritability are already well marked signs. Usually it is stated that in rickets there is a *premonitory* stage in which the child exhibits undue irritability, restlessness, insomnia and sweating about the head and neck, or marked debility with a tendency to lassitude. These observations are inaccurate, for these symptoms occur at the same time and proceed *pari passu* with the changes in the cranial bones and in the growing ends of the long bones. They are in no sense premonitory, but are the result of the active progress of the disease itself. The point is insisted on, for it is only by realising the insidious nature of rickets, its wide distribution throughout the general population, and the very early period at which the child's metabolism is interfered with, that the importance of the rachitic state and its effect on the growth of the manhood and womanhood of the nation can be appreciated. Rickets is not a congenital disease, but the changes begin, as a rule, almost immediately after birth, or within the first few weeks of extra-uterine life. By the time that the wrists are

swollen and tender, and the ribs beaded, and the forehead is prominent, showing a thin white skin and distended veins, and heavy sweats occur, the disease is well advanced and profound changes have already taken place throughout the whole system. Most notable of all, the insomnia and the irritability of the nervous system are signs of marked impairment in the development of the brain itself, which impairment is likely to have a lasting effect on the child's future history.

It is true that it is not uncommon to find that rickets begins after an attack of an acute and debilitating illness such as measles, diarrhoea, or bronchitis. The confinement over a prolonged period, to which the child is subjected, may lead to an attack of rickets from which, but for the acute illness, it would have been exempt, and the date of onset of the rachitic state will naturally depend on the period of occurrence of the acute illness. Thus, it may begin, especially in better class families, at the age of six months or one year, or eighteen months, or even later. But, as a rule, where children are exposed to the conditions which produce rickets, as they are, almost universally, in the slum areas of our large towns, the disease appears soon after birth, and that quite independently of the fact whether the child is breast-fed or bottle-fed, and whether the supply of milk is adequate or no. For it by no means follows that because the parents live in two or three overcrowded rooms, in the slums of our industrial towns, that the feeding is necessarily inadequate. In many cases it is so, but, as we shall see in speaking of the East end of London, and especially of the Jewish section of the population, the feeding is much better than is generally allowed, and the mothers are often in excellent health, and yet the child suffers markedly from the disease. In such areas, the conditions which produce the disease are ubiquitous, and, as a result, nearly all the children pass through a rachitic phase. So insidious is the disease that its presence is usually not noted unless there is an intercurrent illness, which takes the child to the hospital. But the results are noted in the fact

that we unconsciously associate certain types of features and of physical development with slum areas, and accept as natural to these surroundings a type of growth which we recognise does not occur in the wealthier section of the community.

No disease begins at so early a period and none has more far-reaching effects. The defects consequent on the faulty deposition of calcium occurs at a much earlier period than is commonly supposed. Thus in the teeth, as will be seen later, it is common for the enamel which is calcified in the first few weeks after the child's birth to show well marked defects, which frequently continue from this period to the end of the second year, giving rise to the hypoplasia so characteristic of the disease.

The rachitic rosary may be an exceedingly early sign, which is not infrequently met with as early as the third or fourth month. Virchow made the observation that in children dying in the second month a rachitic rosary was plainly visible. To find the characteristic swellings in the region of the wrist and ankle joints, it is usually necessary to wait for twelve or eighteen months, but, by the time this takes place, the disease is already far advanced.

The only reliable information as to the period at which these changes first begin is to be found on histological examination. From this point of view Schmorl's* work is of great value. Histological examination was made of the bones of 386 children dying between the ages of two months and four years, and the signs of rickets were carefully looked for. Out of the 386 cases, 345, that is 89·4 per cent., showed evidence of rickets, while 41, or 10·6 per cent., showed no signs of rickets.

These results closely correspond to the percentage given as the result of a clinical examination of the children in the London County Council schools in the East end of London.†

* "Die Pathologische Anatomie der rachitischen Knochenerkrankung mit besonderer Berücksichtigung ihrer Histologie und Pathogenese," G. Schmorl, Dresden, "Ergebnisse der Innern Medizin und Kinderheilkunde," Vierter Band, 1909, p. 403.

† "Defective Housing and the Growth of Children," by J. Lawson Dick, London, 1919.

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Of Schmorl's 345 cases, showing evidence of rickets, 65 were cases of commencing rickets, 136 were cases of active and advanced rickets, 80 showed rickets in the process of healing, and 64 were actually healed cases.

The following table, from Schmorl's paper, shows the incidence of rickets in the various months of the child's life :—

Number of Children.	Ages in Months.	Rickety Cases.	Cases free from Rickets.
33	2-3 months.	20 = 60.6 per cent.	13 = 39.4 per cent.
34	4-6 "	33 = 97 "	1 = 3 "
53	7-9 "	50 = 94 "	3 = 6 "
75	10-12 "	73 = 97.3 "	2 = 2.7 "
59	13-18 "	58 = 98.3 "	1 = 1.7 "
33	19-24 "	30 = 90.9 "	3 = 9.1 "
65	25-36 "	57 = 87.7 "	8 = 12.3 "
34	37-48 "	24 = 70.6 "	10 = 29.4 "

This table shows that histologically bony changes can be seen as early as the second month, and that from the fourth to the eighteenth month nearly all the children showed evidence of rickets. In another table, Schmorl showed the several stages of rickets according to the age of the child :—

Age in Months.	Commencing Rickets.	Active Rickets.	Healing Rickets.	Healed Rickets.	Total No. of Cases.
	per cent.	per cent.	per cent.	per cent.	
2	4 = 100				4
3	12 = 75	4 = 25			16
4-6	19 = 57.6	7 = 21.2	7 = 21.2		33
7-9	17 = 34	23 = 46	10 = 20		50
10-12	7 = 9.5	45 = 61.7	20 = 27.4	1 = 1.4	73
13-18	4 = 6.9	32 = 55.2	15 = 25.8	7 = 2.1	58
19-24	2 = 6.6	10 = 33.4	11 = 36.6	7 = 23.4	30
25-36		13 = 22.9	14 = 24.5	30 = 52.6	57
37-48		2 = 8.3	3 = 12.5	19 = 79.2	24

This table shows that the bony changes may be seen as early as the second month, and that from the second to the sixth month commencing cases prevail. Between seven

and nine months active rickets is already present. From the tenth month commencing cases begin to fall very decidedly in number ; from one to two years they are few in number, while no fresh cases begin between the ages of two and four years. The disease is most active between the periods of seven months and the end of the first year. The accompanying chart (see Fig. 2, p. 107) is a graphic representation, constructed by Dr. Findlay, of a table of Schmorl's, showing the frequency with which active and healing rickets is met with at different periods of the year.*

The chart brings out the fact previously noted by von Hanseemann, that rickets tends to be active during the spring and the late autumn, and is much less so during the summer, while in the summer months there is a much greater tendency towards healing than in the early and late parts of the year. It will be noted that during the third quarter of the year, the number of cases of commencing rickets is at its minimum, while the number of healing cases is at its maximum. This contrasts markedly with the incidence of diarrhœa.

During the year 1914, out of 12,945 deaths resulting from diarrhœa throughout England and Wales :—

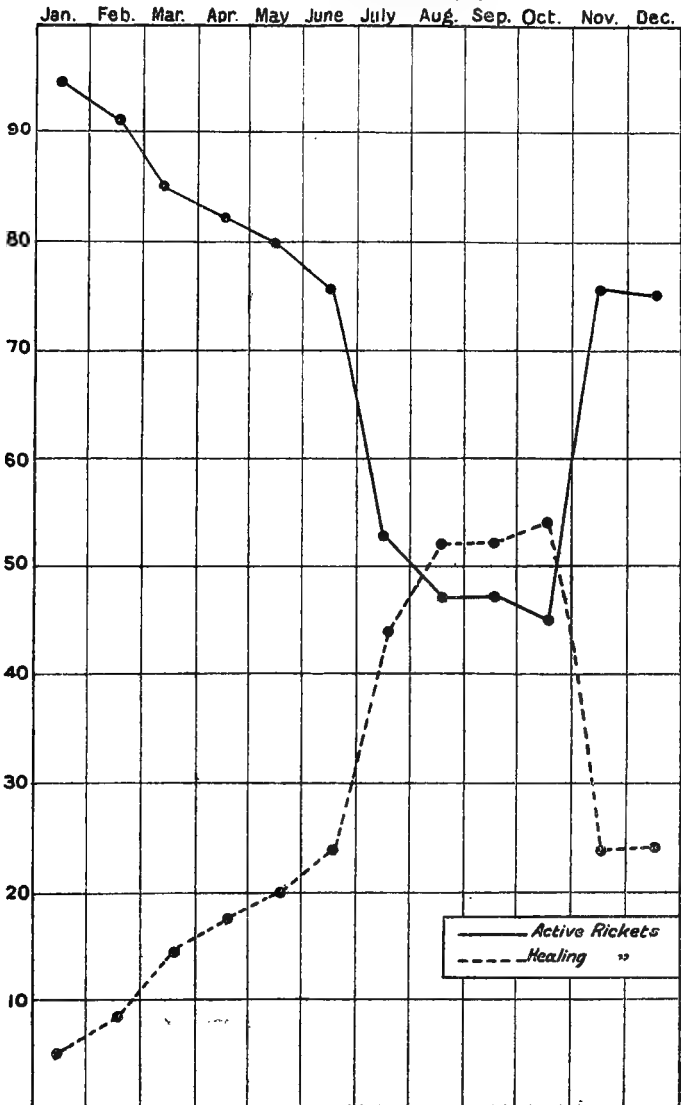
1,444	deaths occurred during the first quarter.
1,362	„ „ „ „ second quarter.
7,352	„ „ „ „ third quarter.
2,787	„ „ „ „ fourth quarter.

These deaths occurred in the general population, but two-thirds took place in the first year, and three-quarters in the first two years, so that they may be taken as fairly representative of infantile mortality. It will be noted that in the third quarter alone, a considerably larger number of deaths occurred than took place during the other three quarters added together. That is, during the period of the year when intestinal infections are most prevalent, commencing rickets is at its minimum, and cases which have been active during the first months of the year proceed

* " Introductory Historical Survey to a Survey of Social and Economic Factors in the Causation of Rickets," National Health Insurance, Medical Research Committee, London, 1918.

FIG. 2.

SHOWING PERCENTAGE OF CASES EXAMINED 386 IN ALL WITH
ACTIVE AND HEALING RICKETS FOR EACH MONTH OF THE YEAR.
COMPILED AFTER SCHMORL.



rapidly towards cure. This is quite incompatible with the statement that rickets has its origin in an intestinal toxæmia.

Schmorl's observations on the early date at which rickety changes can be discerned in the bones of young infants are of great interest. In the infant and young child all forms of bone disease tend to begin at the growing end of the diaphyses of the long bones. Since Parrot's original observations, it has been recognised that in congenital syphilis inflammatory conditions at these sites are very common, and the chief difficulty in diagnosis lies in the similarity of the appearances which some of these infantile bone lesions present to those of rickets. In syphilitic infants it is common to find certain areas in the skull tender and slightly swollen, and the long bones in the region of the epiphyses often suffer in a like manner. These lesions are frequently multiple and may make all movements of the limbs so painful that paralysis may be suspected. Careful examination will often detect tender swellings of the periosteum, near to the junction of the epiphyses and sometimes on the shafts. These swellings are of considerable size, much larger, and at the same time more inflamed than those of rickets.

As Hutchinson points out, if this form of multiple periostitis is seen within six months of birth, it is almost certainly due to syphilis.* In rickets much the same areas are affected, but the nature of the histological change is different and the process is much less acute than in syphilis, though it is also of an inflammatory character.

One of the earliest and most striking signs of rickets is the early appearance of muscular weakness and wasting. The manner in which the child, when undressed, lies placidly across the mother's knees is very characteristic. There is but little effort to raise the head or to move the arms and feet as the normal child strives to do. The distended abdomen is flaccid and deep palpation is easy. At an early period in the disease the whole of the muscles of the limbs and of the body are largely thrown out of action

* "Syphilis," by Jonāthan Hutchinson, London, 1889, p. 83.

and the child moves as little as possible. There are two main reasons for this. First, the respiration of the child is embarrassed at a very early age, and the rickety child avoids all robust movements, such as the normal infant rejoices in, which would be likely to excite the respiratory act. From an early period the rickety child is a silent child. It does not expend its energy in crying, for it is wholly occupied in getting sufficient oxygen into its lungs to supply its present needs. The mechanical act of respiration is a laboured effort which exhausts the child's energies. The only time it is fretful is when it is moved ; when left alone it is placid and silent. The physical condition of the child demands that it should conserve its energies. All voluntary muscular effort is thus limited, and in consequence the muscles tend to become soft and flabby.

The second reason for the very marked muscular wasting which occurs is found in the widespread changes which are already taking place in the bones. As Hilton* points out, when the interior of a joint is in a state of inflammation or of irritation, the influence of this condition is carried to the spinal marrow, and thence reflected to the various muscles of the joint through the medium of the associated motor nerves, the muscles being supplied by the same nerves that supply the interior of the joint. Similar changes occur when these inflammatory changes are in the epiphyses and in the region of the joints, and, as has just been observed, the condition in syphilis may be so extreme as to resemble a paralytic state within the first few months of the child's life. In the rickety infant the process is not so acute, but at a much earlier date than is commonly supposed the muscles tend to be thrown out of action by the inflammatory changes which are taking place at the actively growing bony centres, especially at the junction of the bony ribs with their cartilages and at the ends of the long bones. At a later date, say eighteen months or two years, when the wrists and ankles are distinctly swollen and tender to pressure, one occasionally

* "Rest and Pain," by John Hilton, London, 1887, p. 183.

finds a very similar form of pseudo-paralysis to that already described as occurring in syphilis.

So marked is the muscular debility that it has been suggested that there is an actual structural alteration peculiar to rickets in the musculature. Thus, Bing* describes the following changes, viz., great thinning of the muscle fibres associated with tendency to disappearance of the transverse striation, while the longitudinal striation is markedly accentuated. There is also excessive and diffuse multiplication of the muscle nuclei and replacement of the finer connective tissue by coarser fibres; there is a complete absence of fatty tissue. From these observations, Bing suggests that the histological changes are peculiar to rickets and that they differ from the other myopathies of children. That there is a great loss of function and wasting throughout the whole muscular system is true, but that there are any profound structural changes in the muscular fibres seems unlikely, when the readiness with which even severe cases recover, immediately the environment is altered, is considered. The other suggestion, that there is an enfeeblement or arrest of development of these parts of the central nervous system controlling muscular tone seems more likely, and is in accordance with what we know of the action of rickets on the nervous system. Aschenheim and Kaumheimer examined the muscles of eight rachitic children and three without rickets, and found in all the rickety cases that there was a diminution in the amount of calcium corresponding to the severity of the disease.

This early interference with the proper tonicity and nutrition of the muscles is a symptom of great importance. Nowhere is it of greater importance than in relation to abdominal tension.

Many morbid conditions are recognised as due to alterations in abdominal tension and are credited with producing varied and far-reaching results. Glenard's

* Bing. "Histopathologische und electrodiagnostische Untersuchungen bei rachitischen Kindern mit pseudo-paretischen und atonischen Muskelstörungen." *Med. Gesellsch. Basel.*, Dec. 6th, 1906.

disease, or enteroptosis, occurs in two classes of cases ; one, where the normal support of the abdominal wall is lost in consequence of repeated pregnancies or recurring ascites, and a second and more important group in younger persons, where the prolapse of the viscera is associated with a motley group of nervous symptoms, frequently classed as neurasthenia.

It is not generally recognised how important this one factor of abdominal tension is in the maintenance of health throughout the whole period of life from infancy to old age. Probably no better criterion of physical fitness at any period of life could be obtained than by estimating the value of this one factor of abdominal tension. In the young rickety infant one of the first effects of the muscular debility is the loss of tonicity of the abdominal muscles, and the consequent characteristic distension of the abdomen which is so common a feature of the disease.

Under normal conditions the muscles of the abdominal wall constitute, as it were, a great resilient tube or belt, in which not only is there a continuous elastic support from the tonicity of the muscles, but each individual contraction and relaxation has an influence in helping on the circulation in the great vessels within the abdomen, and in maintaining in their proper position the liver and spleen and the whole gastro-intestinal tract. The continuous elastic pressure on the intestines prevents liquid accumulations and flatulent distension, and aids the action of the involuntary muscular fibre which allows of the three or four motions daily in the healthy child.

It is very different with the rickety child. The laxity of the abdominal muscles rapidly produces the " pot-belly " of rickets. The muscular wall of the intestine soon shares in the general muscular atony and the bowels become distended and lethargic, and there is an unhealthy stagnation of gases and fluids within the abdomen. Constipation rather than diarrhœa is an early feature of the disease. The fæces are usually small in quantity and are light in colour. Not infrequently, especially if cow's milk is given, the

stools are lumpy and pasty and may be coated with mucus. Alternating with this the motions may become loose and very offensive, and it is this irregularity of the bowels, constipation alternating with occasional loose motions, which is characteristic of rickets in its early stages. Very frequently however, the bowels give rise to no trouble. At a somewhat later stage the child frequently finds relief from abdominal discomfort by lying on its face during sleep.

The circulation of the blood and lymph within the abdomen is greatly aided by the healthy contraction and tone of the muscles. In rickets the obstruction is chiefly in the capillary circulation, and lymph stasis leads to a fibroid hyperplasia which, according to Ewart,* accounts for the slighter forms of interstitial proliferation found in the liver and spleen.

The effect of the abdominal atony on the respiratory act is very profound. Normally, in the act of inspiration the chest expands and the contraction of the diaphragm tends to protrude the abdominal wall. The elastic recoil of the healthy abdominal wall is an important factor in the expiratory act. In the rickety child there is little or no movement in the abdominal wall, and this important aid to respiration is lost. At the same time, it is to be noted that the upper part of the chest moves but little, and the diaphragm is chiefly responsible for carrying on the respiratory act. In typical cases, the only region showing active respiratory movement is the inferior costal region, but instead of the normal inspiratory expansion occurring, the mechanical effect of the contraction of the diaphragm is reversed, and a marked recession of the chest takes place during contraction, followed by expansion during expiration. This is the reverse of the normal act. The lower aperture of the thorax is moulded, as it were, over the inert abdominal contents, and the contraction of the diaphragm in place of protruding the abdomen in the normal way produces a

* "The Abdominal Atony of Rickets, its Significance and its Treatment," by Wm. Ewart, M.D., Cantab., F.R.C.P., *British Medical Journal*, 1906, II, p. 920.

direct drag on its attachments to the yielding ensiform and six lower rib cartilages.

The origin of the diaphragm is at the circumference and is alike on both sides. It arises: (1) by fleshy slips from the inner surface of the ensiform cartilage; (2) from the six lower rib cartilages by a series of serrated slips which interdigitate with the attachments of the transversalis abdominis; (3) from two aponeurotic arches between the last rib and the spinal column, one being placed over the quadratus lumborum and the other over the psoas; (4) from the lumbar vertebræ by two crura or pillars, the right from the upper three or four lumbar vertebræ and the interposed discs, and the left from the first and second lumbar vertebræ and the adjacent discs.

From this origin the fleshy fibres are inserted into the trefoil tendon in the centre of the muscle. This tendon consists of a right, a left, and a middle lobe. In the descent of the diaphragm the parts of the tendon move unequally. Thus the central lobe, above which the heart is placed, moves least, while the lateral lobes, above which the lungs are situated, move freely. The extent to which the central tendon descends in full inspiration is estimated by Hasse * at one inch for the right lobe, four-fifths of an inch for the left lobe, and two-fifths of an inch for the hinder part of the middle lobe. The fibres from the ribs ascend vertically, and while the vault of the diaphragm is maintained by the abdominal viscera, the contraction of the muscle elevates and expands the upper ribs to which it is attached. In the rickety subject the diaphragm acts at a double disadvantage: (1) in place of the abdominal viscera being depressed and the abdomen somewhat protruded during inspiration, allowing the natural recoil of the abdominal walls to aid the act of expiration, the abdomen remains immobile, and the diaphragm loses the advantage of the elastic give and recoil of the abdominal wall; (2) the softened ribs have not sufficient rigidity to act as an efficient support for the muscular fibres, and the diaphragmatic con-

* *Archiv. für Anatomie*, 1886, p. 199.

traction actually draws on its attachments, pulling in the lower ribs, as already noted, instead of expanding the chest in the lower costal region.

Rokitansky believed that the changes in the formation of the chest in the rachitic child were due to the recession of the ribs in the act of inspiration produced by the diaphragm in its contraction, associated with want of power in the inspiratory muscles attached to the outside of the ribs. Jenner attacked this view, and ascribed the malformation of the chest solely to the result of atmospheric pressure acting on the softened long ribs, producing the prominent keel-shaped sternum and the longitudinal furrow on either side of it, and also the transverse depression now known as Harrison's sulcus. There is but little doubt that atmospheric pressure is the main factor producing these changes, but clinical observation of the rickety child shows that the reversed action of the diaphragm is also an important factor. In place of the diaphragm acting from a resistant fulcrum, constituted by the ensiform cartilage in front, and the two crura and the aponeurotic arches behind and the six lower rib cartilages laterally, this part of the lever is greatly weakened and shows but little rigidity. At the same time, the central tendon of the diaphragm is maintained in a more or less stationary position by the resistant abdominal mass, which does not move up and down as in health, and the pull of the muscle is deviated from the insertion of the muscle to its origins. If the diaphragm acts forcibly and quickly, as in sobbing, this recession of the most flexible part of the thoracic parietes is most plainly seen, and is a factor of considerable importance helping to produce the collapse of the lower and posterior portions of the lungs, which is so dangerous a feature when the child is attacked by such diseases as bronchitis, whooping cough, or measles.

By these concerted actions the lower ribs are moulded over the liver, and the inert abdominal viscera and Harrison's sulcus is produced, a transverse furrow which begins at the level of the xiphisternum and passes from thence outwards and slightly downwards. The very early and considerable

thickening, which takes place at the costo-chondral junctions, is possibly an attempt on the part of nature to buttress the rib at its weakest point. Similarly, when the action of the powerful muscles of inspiration attached to the outer surfaces of the ribs is considered, the loss of their activity must be a contributory factor in producing the characteristic deformity of the chest.

From a very early date, with the weakness of the muscles is associated great weakness of the ligaments and the other supporting structures of the joints. The relaxation of the joints seems to last for a very long period and is responsible, in a large measure, with the muscular weakness, for the onset at the period of adolescence of such conditions as flat foot, genu valgum and varum, and the various forms of lateral curvature. Even after apparent complete recovery, in the adult there may be a certain degree of genu recurvatum or a capacity for extending the knee beyond a straight line. A similar condition not infrequently affects the elbow joint. Double joint is a very characteristic and well known sign of rickets, which is frequently looked on as an accomplishment rather than as an infirmity, which it really is. These children can assume extraordinary attitudes, and can often place the limbs in unnatural positions, owing to the muscular enfeeblement and laxity of the ligaments. In severe cases, for instance, the child may rest for hours in the sitting posture with the legs extended and with the body bent forwards, so that the face rests on the knees.

Rickets is an insidious disease, frequently beginning, as Schmorl has shown, in the second month, but not usually recognised till the sixth or eighth month, by which time it is already well advanced. The nervous symptoms appear very early. The child becomes dull, peevish and irritable. There is, in well marked cases, a general tenderness of the whole body and the patient courts rest and resents being handled or interfered with. The sweating of the head and neck during sleep is a characteristic early sign.

The state of the general nutrition in rickets has already been touched upon. In eight hundred rachitic children in

the East end of London, it was found that eighty per cent. were of good or of very good nutrition, while in only twenty per cent. could the nutrition be said to be distinctly poor. The child, especially if fed upon the breast, frequently looks well nourished and healthy. At other times the infant does not increase in weight satisfactorily and the muscles are soft and flabby. But marked wasting is by no means a constant sign, even in severe rickets, and in deaths from marasmus there is generally no sign of rickets. Wasting in the young infant of from a few days old up to the end of the second or third month is a much more common sign of hereditary syphilis than it is of rickets, especially in the syphilitic form of pseudo-paralysis. In such a case the child looks cachectic and has an old expression. The skin is dusky and shrivelled and the eyelids and lips may be fissured. Coryza, hypertrophy of the liver and skin eruptions are common in syphilis. Such a series of symptoms is uncommon in rickets, especially at this early stage. The very fat, flabby and pale-complexioned child is well known in rickets. Frequently in these cases nothing abnormal is suspected till delay in teething or in walking draws attention to the fact that the child is not progressing as it should.

CHAPTER IX

Changes in the Bones of the Vault of the Cranium and in the Bones of the Upper and Lower Extremities visible to the Naked Eye

Changes in the skeleton visible to the naked eye.

As has already been seen, these begin insidiously and at a very early age, and Schmorl, as the result of actual microscopical examination, found that the bony alterations might begin as early as the second month. Frequently they are overlooked in the early stages by both the parent and the physician, and in the milder cases they have to be systematically looked for ; but when this is done they are usually fairly obvious. The skeleton, as a rule, is affected as one organ by the disease, but the structural alterations may be more marked at certain parts. In the young child the changes show a definite symmetry. They affect the long bones mainly in the growing ends of the bones, in and around the layer of cartilage lying between the diaphysis and the epiphysis, where the bone is growing in length by ossification in cartilage, and at the circumference of the shaft where the bone is increasing in thickness by ossification in membrane (periosteum).

In the flat bones of the skull the errors in growth tend to manifest themselves at the growing borders in the neighbourhood of the sutures, and at the centres of ossification in the region of the natural eminences of these bones, where swelling and softening of the osseous tissue are usually well marked.

Changes in the flat bones of the vault of the cranium.

The most marked and the earliest alterations appear in the flat bones forming the vault of the cranium. The

tendency to delayed closure of the fontanelles and sutures has already been noted ; in place of closing on or about the age of two years, the anterior fontanelle may still be widely open, and may not close until the third or fourth year, or even later. Normally, the most rapid growth in the cranial vault is focussed round the anterior fontanelle, and for this reason closure does not take place in the healthy child till about the end of the second year. In rickets there is a general holding-up of the growth, not only of the skeleton as a whole, but also of the nervous system, and for this reason the closure of the fontanelle is much delayed, allowing a longer period for adaptation to the needs of the more slowly developing brain.

When rickets begins early, the cranial changes are not, as a rule, very notable clinically till the fifth or sixth month. It will be remembered that this period tends to coincide with the disappearance of cranio-tabes, which is so common and so evanescent a change in many childish ailments. Frequently in mild rachitic cases there is only a slight swelling in the neighbourhood of the parietal and frontal eminences and along the edges of the bones bordering the sutures. These changes may be very slight and may pass off without producing any characteristic deformity. When the alterations are more persistent in the frontal region, the forehead tends to become large and square. It is both wide and high. The frontal eminences show bossing, forming what is known as the Olympian type of forehead, very commonly seen in the rachitic child to-day.

In many diseases, especially those which affect growth and development, there is a tendency to reproduce a certain type. This is conspicuously true of acromegaly, where all the cases look as if they were members of the same family. Similarly in a disease like rickets, which may pervade a whole nation, these very deformations may come to form a national type. Later, in discussing the history of rickets, reasons will be shown for believing that, before the disease actually developed in England, it was already well established on the Continent, notably in the low-lying country of

Flanders, and in the great commercial and industrial centres of the Hanseatic League. Indeed, the high square forehead or *front Olympien* came to form a national ideal of dignity and beauty, and is constantly depicted as such by the Flemish school of painting.

Not only, however, is the frontal region affected, but a similar overgrowth takes place in the parietal region. The bossing in the region of the parietal eminences is often exceedingly well marked and is a much commoner and more persistent sign than the frontal bossing. In placing the hands on the heads of school-children for the purposes

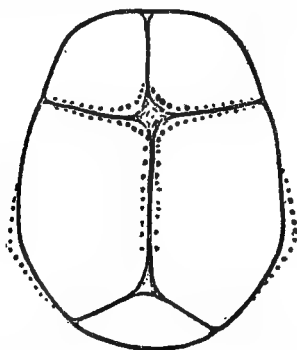


FIG. 3.—Infant skull showing position of parietal bossing and the thickening along the coronal and sagittal sutures, the characteristic cranial signs of rickets.

of palpation, this is the sign which is much the most frequent and is often very conspicuous. The borders of the parietals may show thickening and the sagittal suture may come to lie in a groove or hollow. (Fig. 3.) On the other hand, as already pointed out, the process may lead to softening and thinning of the borders of the bones, and if the changes occur in the first few months cranio-tabes may develop in the region of the posterior border of the parietals. It will be observed that the alterations described in the frontal bones and in the parietals closely resemble those met with in congenital syphilis. When these changes occur early it is not always easy to distinguish between syphilis and rickets. In the syphilitic lesion there is a more acute

inflammation and the swollen areas are more tender. When the frontal bosses and the parietal bosses are both well marked, constituting the natiform skull or the *caput quadratum* of Parrot, the condition, as Parrot correctly pointed out, is usually syphilitic. In pure rickets the natiform head is by no means common. In the rachitic subject, when the frontal bossing is well marked, the high intellectual-looking forehead is apt later to become consolidated into the forbidding, overhanging type of forehead so characteristic of many slum dwellers. In these cases the parietal bossing is not well marked and the head may assume the doliocephalic type. In the commoner class the parietal bones are chiefly affected and the deformation of the frontal region is but little marked or is entirely absent, and the skull tends to assume the brachycephalic type characteristic of rickets. It is worthy of note that in the rachitic state the disease seems to concentrate either on the parietal or the frontal region, but not on both at the same time, while in syphilis the tendency is for both frontal and both parietal bones to be simultaneously affected.

Throughout the skeleton rickets manifests itself chiefly at the points where growth is proceeding most rapidly. In the flat bones of the vault of the skull it is most marked at two parts, viz., the centres of ossification and the rapidly growing borders. Of all the bones of the cranial vault, the parietal bone is the chief centre of growth, and therefore it is not surprising to find that it is usually the bone most markedly affected in rickets. If the disease is severe and continued, more advanced changes occur. Towards the borders of the bone the outer surface becomes more vascular, somewhat swollen and slightly roughened, and the outer table loses its shiny appearance. This roughened surface becomes somewhat elevated above the level of the adjacent smooth bone by the formation of a light, finely porous and friable bone which, in the dry specimen, has very much the appearance of pumice stone.

This change is usually very definitely symmetrical and progresses from the margins of the bone towards the centre of



PLATE I.

Frontal bone of an infant showing well marked rickety changes. The greater part of the bone is thickened and is converted into a light, dry, finely porous and friable tissue. This porous, spongy bone has much the appearance of fine pumice stone and is slightly raised above the level of the smooth compact bone which still remains. The change is symmetrical and progresses from the circumference of the bone towards the centres of ossification which, with an area round, are free from the disease. The inner surface of the bone shows the same changes, somewhat less advanced.—*Hunterian*.

ossification, which, however, with a variable space round it, usually retains its smooth compact appearance (see Plate I). In severe cases the inner surface of the bone may also be roughened, though the changes are usually much more marked on the external aspect. On both surfaces the openings for blood vessels are more numerous and larger than in health. When the inner surface is much roughened, remains of the smooth compact bone of the inner table may still be seen in areas corresponding to the spaces between the cerebral convolutions. At a later stage the disease may involve both the outer and inner tables, and the diploë, and the thickness of the bone may become very greatly increased. The bone throughout its thickness is frequently converted into a uniform finely cancellous tissue, in which there is no distinction between tables and diploë. At times the thickening may be very considerable, even from four to six lines. On the inner surface of the bone there are large grooves for the meningeal arteries, and the apertures for the blood vessels are especially large and numerous. In the dried specimen the bones throughout are finely cancellous, the cells being small and irregular in form and lined by tortuous lamellæ. The bone is light and brittle in texture and may, in the dried specimen, be easily converted into a coarse powder.

At a still later stage a reparative process occurs, by means of which this loosely cancellous bone becomes consolidated. The walls of the various cells become thickened till their cavities are greatly reduced, and in place of the bone being light and porous it tends to become solid and heavy.

In the rickety skull there is frequently an appearance as if the cranial capacity were considerably increased. Apart from hydrocephalus, this is practically never the case. Either the capacity of the skull remains normal, or when the thickening is very great it may be considerably encroached upon.

Several stages then can be noted in the progress of the disease in the membrane bones of the cranial vault, viz. :—

1. a general softening and swelling of the bone chiefly affecting the outer table. Frequently, the process never goes

beyond this stage, and there may or may not be slight bossing over the centre of ossification as a result. In young infants, up to the sixth month, certain areas may, as a result of pressure, become thin and atrophied, and cranio-tabes may be produced :

2. as a result of an extension of the disease, new light cancellous bone is formed, which projects slightly beyond the level of the outer table and tends to replace it. This is usually associated with some roughening of the inner table, but at this stage the disease is usually more marked on the outer surface :
3. in severe cases the whole thickness of the bone may be involved, so that the distinction between inner and outer tables and diploë is lost, and the structure throughout is uniform, light, and porous :
4. a reparative process occurs whereby the bones become consolidated and indurated, not only by recalcification, but also by the formation of new lamellæ thickening the walls of the cells till these are reduced to minute pores.

It is important to remember that when this process of consolidation takes place it is remarkably persistent and may not disappear throughout life. It is quite commonly seen in the adult, in the heavy forbidding forehead, and the overhanging eyebrows of the slum dweller who has suffered somewhat severely from the disease and over a prolonged period.

The bones of the face also participate in the rachitic process. Both maxillæ are liable to be affected, but the most notable changes take place in the superior maxillæ. These alterations are peculiar in that their manifestation is delayed, as a rule, till a considerably later period, usually about the period of second dentition. These changes are part of a connected process associated with such conditions as post-nasal obstruction due to adenoids, mouth breathing, and chest deformation, and will be best dealt with when speaking of alterations in the function of respiration in rickets and their effects on the growth of the upper jaw and the bones of the face.

Changes in the long bones.

Jules Guérin, in his celebrated observations on the pathology of rickets, in 1837, described two stages : (1) a



PLATE II.

Longitudinal section of rachitic femur, slightly reduced.

1. Greatly thickened and irregular layer of intermediary cartilage.
2. Long process of cartilage extending into the osteoid tissue.
3. Islands of cartilage surrounded by osteoid tissue.
4. Osteoid tissue merging into the fibrous and partially calcified trabeculae of the medulla.
5. Greatly thinned and expanded periosteal bone with formation of osteoid tissue under periosteum.

period of effusion and proliferation associated with rarefaction ; (2) a period of deformation and of organisation of the tissues which have undergone proliferation.*

In the first stage the bone is easily bent and is soft, so that it may be cut with a sharp knife. If a section of the bone be made in its long axis, splitting the bone into two halves, it will be noted that there is considerable proliferation of the medullary tissue, which is softer and redder than normal. The medullary cavity tends to be actually increased by the enlargement of the areolar spaces and by the rarefaction and absorption of the compact bone. At the same time, there is a swelling of the intermediate semi-transparent bluish zone of cartilage, between the diaphysis and the epiphysis. On examination by the naked eye, this is seen to be increased in thickness and to have a reddish colour, owing to abnormal vascularisation. It is markedly irregular, and at times long processes of partially calcified cartilage can be seen extending upwards into the osseous spongy tissue, or there may be isolated islands of cartilage surrounded by new bone (see Plate II). A double process is going on.

At the same time that there is a rarefaction of the pre-existing healthy bone, there is a formation of osteoid tissue, especially in the region of the zone of ossification at the epiphysial ends. This takes place on an exaggerated scale. All the scaffolding, as it were, for the new growing bone is erected in excess, but the actual building of the bone falls far short of the preparations made. The enlargement of the ends of the long bones and the beading of the ribs are due to this overgrowth of the layer of cartilage and to the formation of ill-formed, spongy bone.

In mild cases, the periosteum and the sub-periosteal layers may exhibit no marked structural alteration, but when the disease is a little more intense these tissues usually show changes. The periosteum is much thickened and soft and

* Jules Guérin, "Mémoire sur les caractères généraux du rachitisme," *Bull. de l'Acad. du méd.*, 13 Juillet, 1837, et *Compt. rend. de l'Acad. des Sciences*, 1839.

shows increased vascularity. It is less easily stripped off than in the normal subject, and when so stripped it is rough and irregular, bearing numerous spicules and fragments of ill-formed osseous tissue on its inner aspect. The compact bone beneath the periosteum may be greatly thinned and is often replaced by concentric layers of soft spongy bone. This new bone, or osteoid tissue, is imperfectly calcified and readily allows of curvatures of the bone, and even of fractures if a sudden force is applied to it.

The two processes, then, which are characteristic of rickets are, as Guérin pointed out, a process of medullisation and the formation of spongy bone. These processes, as a rule, proceed together in the same bone, though the medullisation is the first change which occurs. In this process the medulla or bone marrow increases in volume and becomes redder than normal. It is much softer than natural and there is much fluid not contained in the blood vessels. Following the increase of the medulla, the cancellous spaces in the shaft and towards the end of the bone become enlarged, so that the medullary cavity as a whole actually becomes expanded. Under the periosteum the laminæ of the compact bone are split up and a rarefaction of the compact bone begins, and it tends to be replaced by spongy bone or osteoid tissue. While this spongy bone is formed under the periosteum, it is mainly found between the medullary cavity and the epiphyses at the diaphysial end of the long bones. This tissue is soft and spongy, with many fine spaces, and cuts easily with a knife, a grating sensation being imparted to the edge of the knife, owing to the imperfect calcification which has taken place.

In the long bones, as in the flat bones of the skull, the rachitic process tends to end in repair. The medulla loses its red colour in the shaft of the bone and becomes less abundant. The spongy tissue becomes paler and the excess is in part absorbed, and in part becomes consolidated. New lamellæ are formed in the spaces of this spongy tissue, which gradually becomes transformed into a dense compact bone, harder and denser than normal bone, so that it has an ivory-

like appearance on section. This new bone is especially abundant in the concavity of the bend in the shaft of the bone, but in the tibia it frequently encroaches very largely on the medullary cavity, owing to the deposit of new dense compact eburnated bone on the medullary aspect of the shaft.

The following sites are the parts of the skeleton most frequently and most vigorously attacked by rickets. The anterior extremity of the ribs seems to be the part for which rickets has the chief affinity. Next, in early cases, come the bones of the vault of the cranium, and after this the inferior extremities of the femur, radius and ulna, and the tibia and fibula. Following this in order come the superior extremity of the humerus, the vertebræ and the iliac bones, while the sternum is but rarely affected.

CHAPTER X

Microscopic Anatomy of the Bony Changes in Rickets

Microscopic changes in the bone in rickets.

THE work of Virchow, published in 1853, on the minute anatomy of the changes which take place in normal ossification and in the rachitic process, constitutes an important landmark in the study of this disease.* It has formed the model for most of the subsequent work which has been done on the subject. Most observers have not been able to break away from his authority or to extend the scope of the enquiry, and the study of the pathology of rickets has largely limited itself to an examination of the changes which take place in the bone and cartilage, and but little attention has been paid to the important structural alterations which occur elsewhere throughout the body.

Already, in the fifth week of the life of the infant, Virchow found that, as the result of rickets, there was a retardation of the process of bone formation, and an unequal and irregular growth in the region of the line of calcification of the cartilage.

The first notable change takes place in the medulla. The medulla or marrow normally fills up the hollow of the shaft of the long bones and occupies the cavities of the cancellated structure, and it also extends into the larger Haversian canals. The medullary cavity and the cancellæ are lined by a medullary membrane which, however, cannot be detached as a continuous structure. In the healthy adult, the marrow which fills the cavity in the shaft of the long bones differs

* "Das normale Knochenwachstum und die rachitische Störung desselben," von Rud. Virchow, *Archiv. für Pathologische Anatomie und Physiologie und für Klinische Medicin.* Fünften Bandes, viertes Heft, 1853.

from red bone marrow, and is of the character of ordinary adipose tissue, the fat cells being supported by a kind of retiform tissue, while between them, cells similar to those found in the red marrow occur. In the cancellated ends of the long bones, in the ribs, and notably in the cranial diploë, the medulla is of the nature of red marrow, which contains very few fat cells.

In the foetus and in the young infant, the marrow filling the general medullary cavity in the shaft of the long bones, unlike what is found in the adult, is of the nature of red marrow, and the cells have the power of aiding in the building up and the absorption of bone. In the adult, the marrow cells lose their osteogenic function, and the medullary tissue probably takes no part in the formation of new bone. Soon after birth fat cells begin to be deposited in the medulla of the shaft, but at birth they are conspicuously absent. It is another illustration of the erroneous observation that the new-born infant is a storehouse of fat.

When the rachitic process begins the fatty element of the marrow tends to rapidly disappear. Proliferation takes place in the cells of the medullary spaces. According to Marfan, this increase takes place chiefly in the nucleated red blood corpuscles and in certain large multi-nucleated cells (eosinophile myelocytes), while the still larger giant cells or myeloplaxes, which, according to Kölliker, play such a large rôle in the absorption of bone in the process of normal ossification, do not appear to be more abundant than in health. In rickets these giant cells do not seem to take much part in the process of rarefaction which is a conspicuous feature of this disease.

The blood vessels of the medulla are dilated, and in them may be seen small infarcts consisting of clumps of red blood corpuscles, or there may be minute hæmorrhages with traces of pigment. If the disease is acute, medullary cells appear under the periosteum, where they are not usually found, though osteoblasts in large numbers occupy this situation in health.

In the process of normal bone formation, several layers

may be noted in the cartilage at the end of the long bones lying between the shaft or diaphysis and the epiphysis. Furthest away from the actual line of ossification there is a comparatively quiescent layer of ordinary hyaline cartilage. Next to this, and nearer to the line of ossification, there is a layer of actively proliferating cartilage where the cells are swollen and are rapidly dividing. In the zone where ossification is taking place normally, these cells arrange themselves in rows and are somewhat flattened transversely to the long axis of the bone. In the trabeculæ between these columns of cells, a process of calcification goes on leading to the formation of primary or temporary bone.

In normal bone capillary loops come from the vessels of the bone marrow and are, as it were, held up by this layer of calcified cartilage. Gradually, however, as these vascular loops covered with medullary cells approach the calcified cartilage, certain of the cell columns break down and the blood vessels pass into the cell columns between the calcified trabeculæ, carrying the osteoblasts with them. These apply themselves to the trabeculæ and begin to form new bone on the remains of these calcified cartilaginous processes. This is a regular and ordered process, and is very different to what takes place in rickets, where the blood vessels penetrate far and wide into the partially calcified cartilage.

In rickets three stages of the disease are generally described—the incipient stage, the florid stage, and the period of healing. The first essential part of the rachitic malady is a holding up and delay of the normal process of ossification. The enlargement at the epiphysial end of the long bones at first sight appears to be due to the excessive production of cartilage. It is true that an overgrowth of cartilage does take place, but in the main the enlargement is due to the fact that ossification is much delayed and proceeds very slowly, so that the cartilage does not become converted into the properly calcified and more compact bone. The layer of cartilage between the epiphysis and the diaphysis, where it abuts on the capillary loops extending from the marrow, has failed to undergo the usual provisional

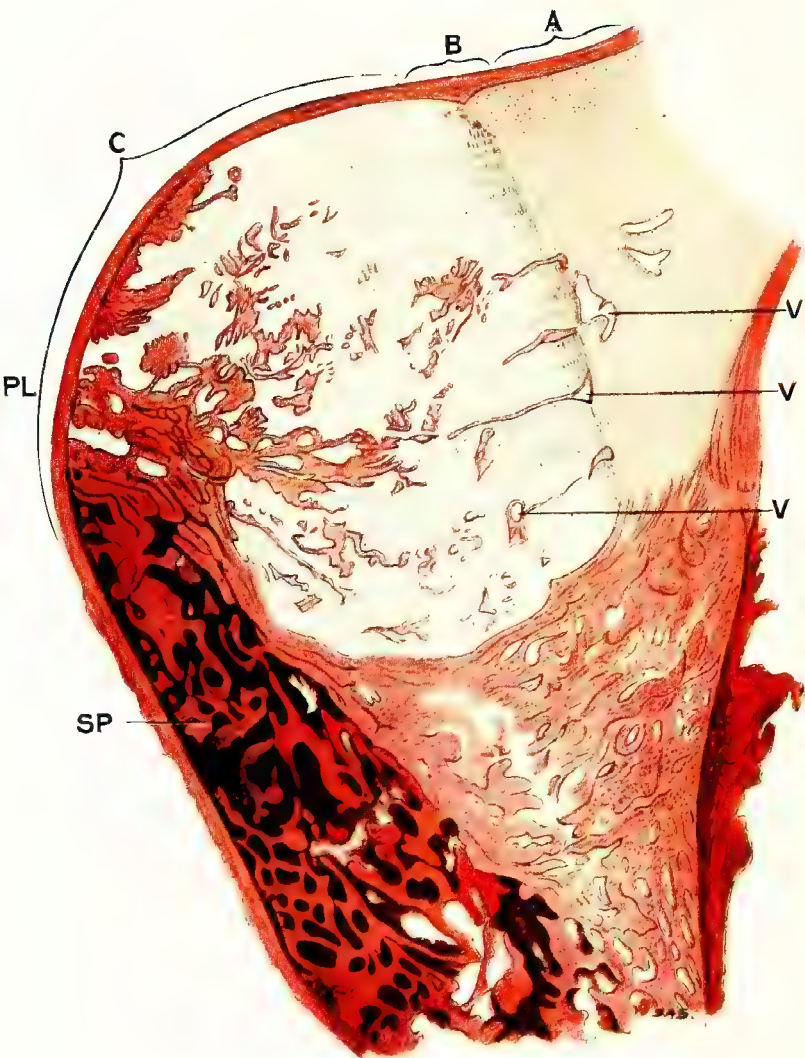


PLATE III.

Longitudinal section through the junction of a rib and its cartilage from a rickety child of eighteen months, X, 10, Kassowitz.

PL, Pleural side.

A, Normal cartilage.

B, Proliferation zone deeper than normal.

C, Columnar zone, enormously increased and showing islands and processes of osteoid tissue deposited round the blood vessels spreading from the spongy layer and from the perichondrium.

SP, Spongy tissue with wide spaces filled with grumous material, containing many cells.

v, Blood vessel.

calcification, or at most has been calcified very irregularly. As a consequence the capillary loops, instead of being arrested at this calcified area, penetrate readily into the cartilage and spread far and wide, splitting it up in all directions. The osteoblasts which are carried in with these blood vessels immediately proceed to the formation of new bone, but the process is only partial. A tissue which has morphologically the appearance of true bone is laid down in the form of thick irregular laminæ, but the laminæ do not become properly calcified. This is the osteoid tissue which plays so important a part in rickets.

But the cartilage is not only invaded by the vessels from the medulla. From the periosteum an abundant overgrowth of vessels takes place, penetrating the epiphysial cartilage. These split up the cartilage and end in a network of small vessels, running for the most part parallel to the plane of ossification. This vascularisation of the cartilage, which is normally present in the foetus, is quite abnormal after birth. The free supply of blood vessels from the medulla and from the periosteum, splitting up the cartilage and carrying with them the medullary cells right into the substance of the cartilage, is quite irregular and is one of the early and reliable signs of the disease. As a consequence, the cartilage becomes excavated in all directions, and a medley of all the processes of ossification results. Irregular masses of imperfectly formed bone lie in the midst of the much expanded cartilage layer on the one hand, while on the other, islands or processes of partially calcified cartilage extend far into the osteoid tissue, which has been laid down (see Plate III).

Not only, however, is there a holding up of the normal ossification, but a process of rarefaction precedes and continues *pari passu* with the formation of osteoid tissue. This rarefying process is greatly in excess of what takes place in healthy growing bone. The medullary cells are the active agents promoting the absorption of bone, but, according to Marfan, in rickets this process is not carried out by the myeloplaxes which produce absorption in normal ossification.

As a result of the rarefying osteitis in rickets there is an enlargement of the areolar spaces of the spongy bone and of the cancellated spaces of the medullary cavity. Osteoid tissue, that is tissue which has the morphological structure of bone, but which is imperfectly calcified or entirely uncalcified, is formed in two ways, firstly, by the absorption of lime salts from old bone which has been previously calcified, and secondly, by the laying down of new bone which has never been calcified. The increase in bulk of the cartilage and the formation of the osteoid tissue which takes place, especially towards the diaphysial end of the bone, together form the swelling noted at the epiphysial end of the long bones and also the beading at the costo-chondral junction of the ribs.

Meanwhile, in the shaft of the bone changes are also taking place. The medulla, which has acquired the character of red marrow, passes, as has been seen, under the periosteum and into the Haversian canals. As a result of this intrusion rarefaction takes place and the Haversian canals are enlarged, and the layers of compact bone underneath the periosteum become first of all softened and the laminæ become detached. If the disease is at all severe, the compact bone is decalcified and softened and may be entirely removed and be replaced by osteoid tissue newly laid down. In severe cases the compact layer of bone under the periosteum may be very thin, and it can readily be understood that such a bone is liable to fracture from very slight violence. So that even under the periosteum of the shaft, osteoid tissue is found, and it is especially abundant where perforating vessels pass through the compact bone from the periosteum to the medulla. As the disease progresses the marrow tends to become much more fibrous, and laminæ of bone or masses of osteoid tissue may be present in this fibrous marrow.

In the flat bones of the skull the swelling of the parietal or frontal eminences is due to the formation of soft and spongy osteoid tissue, which may subsequently become entirely absorbed if the rachitic state be slight. If the

rickets be severe and prolonged, the spongy bone tends to become organised and consolidated by becoming completely calcified, and by the laying down of fresh laminæ in the areolæ, so that the former spongy tissue is converted into hard and dense bone. When this latter change takes place it is wonderfully permanent, and is quite commonly seen to persist in the dense thickened skull bones of the adult of forty years. This is especially noticeable when the reconstruction takes place in the thickened bone of the frontal region.

In rickets the interference with the building up and moulding of the bone is very marked. But at no time does the process, as it were, get out of hand. The confusion which occurs is at times very marked, but there is always a very ready tendency to recovery even in advanced cases. When this takes place new laminæ are laid down in the areolæ of the spongy bone, and these new laminæ and the spongy bone become completely calcified. Faulty bone is removed by a process of absorption and considerable curves in the bone may become straightened out. When the curvature of the bone is well marked, or the disease severe and prolonged, the give in the bone may not be corrected, and in the rebuilding of the bone strong buttresses are often thrown out strengthening the concavity of the arch.

In the florid stage of the disease there may be minute infarcts within the capillaries and smaller vessels or there may be minute hæmorrhages. But the process is more controlled than are the changes which occur in the same situations as the result of scurvy. In scurvy the cartilage has the appearance of having been driven with some violence into the softened bone, so that the laminæ and trabeculæ lying underneath the cartilage are splintered and strewn about in all directions.* Hæmorrhages are common, and, especially under the periosteum, are liable to be extensive and severe. How far the scurvy is responsible for the beading of the ribs it is difficult to say. That it has some influence in producing the condition seems probable from

* Hess, "Scurvy Past and Present," 1920.

the histological picture, which differs considerably from that produced by rickets. It must be remembered, however, that while Barlow's disease is a true scurvy, it frequently occurs in a rachitic subject. The probability is that the change is essentially rachitic in these cases, but that super-added to it there are the more acute changes which occur in scurvy. In the ordinary way, it may be safely inferred that if the child has a well marked rosary the condition is due to rickets. Scurvy is a well defined disease and is a comparatively rare condition in this country. It is an acute affection which definitely menaces the life of the child, and to include under the term scurvy various forms of anæmia and conditions of ill-health due to defective and deficient feeding and to faulty nourishment is not warranted by what is known of the disease. It is due to the continued want of a specific accessory food factor essential to the maintenance of health, and if the deficiency be severe enough to produce scurvy the symptoms are very distinctive and the menace to the child's life is a very real one.

The nature of the bony changes in rickets.

The chemical study of the bones in rickets has not added greatly to our knowledge of the disease. The following table, taken from Vierordt shows, what is now well established, that there is a marked deficiency in the proportion of inorganic salts in the bones in this disease, but that the proportion of the different salts is the same as in normal bone.*

There are two chemical theories explaining the process of normal calcification and ossification. The first is that chemical precipitants are formed in the tissues from nucleoproteins, possibly by a process of autolysis. Autolysis is a process occurring in cell degeneration whereby, probably as the result of enzymes, a form of self-digestion occurs within the cell. The chemical precipitant, it is suggested, may be phosphoric acid formed by breaking up of the

* "Chemical Pathology" by H. Gideon Wells, Ph.D., M.D., Philadelphia and London, 1920.

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nucleo-proteins of the cartilage cells, which combines with the calcium from the plasma. The administration of phosphorus has long been a recognised form of treatment for rickets, and is considered by many of the nature of a specific.

	Normal bone of a two months old child.		Rachitic bones.				
	Tibia.	Ulna.	Femur.	Tibia.	Humerus.	Ribs.	Vertebrae.
Inorganic matter ...	65.32	64.07	20.60	33.64	18.88	37.19	32.29
Organic matter ...	34.68	35.93	79.40	66.36	81.12	62.91	67.71
Calcium phosphate...	57.54	56.35	14.78	26.94	15.60	...	...
Magnesium phosphate	1.03	1.00	0.80	0.81			
Calcium carbonate ...	6.02	6.07	3.00	4.88	2.66	...	...
Soluble salts...	0.73	1.65	1.02	1.08	0.62	...	...
Collagen (or ossein)...	33.86	34.92	72.20	60.14	81.22	...	...
Fat	0.82	1.01	7.20	6.22			

The second view, elaborated by Wells, is that ossification depends on physico-chemical factors and variations in the carbonic acid content of the blood. Wells points out that all tissues about to become calcified undergo retrogressive changes, such as hyaline degeneration as in cartilage, or necrosis. Thus these tissues tend to assume a similar physical character. Further, in the areas about to become calcified the circulation is feeble, and the blood plasma soaks slowly through the tissues as through a foreign substance. These hyaline structures, besides showing an affinity for calcium, also show an affinity for pigment and iron. This is conspicuously seen in the enamel of the teeth in the brown lines of Retzius. Hofmeister believes that normally the blood which comes to the cartilage has a higher degree of saturation with calcium salts and carbonic acid gas than the fluid is able to maintain as it slowly permeates the cartilage, and that when this carbonic acid content is diminished calcium salts are precipitated.

Wells implanted various tissues into the abdominal

cavities of rabbits, and found that tissues rich in nucleo-proteins showed no tendency to take up calcium in greater amounts than did tissues poor in nucleo-proteins, which speaks against the theory that phosphoric acid derived from nucleic acid combines with the calcium. On the other hand, a piece of boiled cartilage placed in the abdominal cavity rapidly became thoroughly impregnated with calcium and salts, which seemed to be deposited, as regards carbonate and phosphate, much as in ordinary bone. Wells favours the second view, that changes in the physical characters of the tissues and variations in the carbonic acid content of the blood are the chief agents in rickets preventing the laying down of calcium salts at one time and causing their absorption at another.

The crude views which have been put forward from time to time that rickets is due to the absorption of calcium salts from the bones by free acids, or other acid molecules circulating in the blood, have been largely abandoned in so far as they are contrary to everything that is known of the chemistry of the blood. Nor are the changes in rachitic bone at all comparable to the changes which are produced by a simple removal of calcium salts, such as would occur from placing the bone in an acid medium.

Neither are calcium poor foods now held to be an active agent in the production of rickets. Stoeltzner has shown that while young animals fed on food deficient in calcium show defective bone formation, the defect is simply a quantitative one, and that the pseudo-rachitic bone shows a notable affinity for calcium salts and undergoes rapid calcification when these are supplied.*

It has been maintained that in rickets there is a simple arrest of or a delay in the metabolism, but, as has already been shown, there are essential anatomical differences between the osteoid tissue laid down in this disease and that laid down in health, which could not be explained by a simple holding up of the normal process.

* "Pathologie und Therapie der Rachitis," von Dr. Wilhelm Stoeltzner. Berlin, 1904.

Virchow first expressed the view that the changes in this disease were essentially of an inflammatory nature, and that they are due to an irritative process of the nature of a rarefying osteomyelitis. Kassowitz and Ziegler have strongly supported this view. That the changes are essentially inflammatory in their nature seems certain, when the changes in the bone marrow cells and in the connective tissue basis of the medulla are considered, and also the active swelling and proliferation which occurs in the cartilage cells. Furthermore, there is the evidence of the hyperæmia and the proliferation of blood vessels in the medulla, and the invasion of the cartilage, not only from these vessels but from the periosteum. Now there are all degrees of irritation and of inflammatory response, and in rickets the process is essentially a sluggish one, distinguishing it very markedly from the acute processes which occur as the result of experiments in animals, notably dogs, and in animals under confinement. There is an absence of acute cellular infiltration and of fibrinous or purulent exudates, and hæmorrhages are not common. Ziegler believed that the inflammatory process chiefly affected the endosteum, or membrane which lines the medullary space, and the areolar spaces of the cancellous bone.

The probability is that the process is of a double nature, and that an inflammatory response to an irritant runs *pari passu* with a delay of all the normal processes of ossification, and indeed of most of the metabolic processes throughout the body. Marfan* lays great emphasis on the early changes which take place in the medullary tissue and in the cells of the cartilage, more especially of the former. As already pointed out, the marrow cells in the medullary space and in the areolar spaces of the cancellous tissue at the ends of the long bones divide rapidly and the whole tissue becomes unduly vascular. Fibro-vascular bundles invade the cartilage, the Haversian canals and the interstices of the compact bone extending, as has been shown in well marked cases, right up under the periosteum. The ossifying

* Marfan, *loc. cit.*, pp. 324-332.

cartilage participates actively in the irritative process, for the cartilage cells also swell and divide abnormally. Like all inflammatory processes, these irritative changes tend to end in the formation of new fibrous tissue, and in time, in place of the actively proliferating, very vascular medulla, there is a tendency for the marrow to become harder and more fibrous than normal, and for osteoid tissue to be deposited in the trabeculæ.

But, before this further change takes place, there is also a notable arrest of the normal process of bone formation. New bone is not laid down, and the process of decalcification and absorption of old bone, which normally occurs, still continues and is probably exaggerated. In place of new bone formation, there is an excessive laying down by the osteoblasts of osteoid tissue, resembling new bone morphologically but with well marked difference in the form and arrangement of the laminae. This imperfect tissue is deposited chiefly in the vicinity of the growing centres of the long bones, and, owing to the irregularity of the cartilaginous overgrowth in this region, cartilaginous tissue appears in the spongy bone and spongy bone in the cartilage. As the process of absorption of old bone continues in other situations, for example, under the periosteum, so it tends to be replaced by this imperfect osteoid tissue.

These changes will again be discussed in speaking of the ætiology of rickets, and it is important to remember the double nature of the process, consisting of a slow, indolent inflammatory change, with an arrest, more or less complete, of the normal ossification.

Such then, are some of the changes occurring in the bone in rickets. Frequently, these changes in the skeleton are treated as if they embraced in themselves the whole pathology of the disease. That this is far from the truth will be shown in the following chapters, where marked pathological variations will be found to occur in the teeth, skin, eyes and nervous system, and very notably throughout the lymphatic system. The changes in the nervous system have not yet

been demonstrated, but by analogy, and from the very definite line of nervous symptoms produced, such changes may be reasonably inferred.

Rickets is an insidious disease and has far-reaching effects on the whole economy of the growing child.

CHAPTER XI

Common Deformations produced in the Long Bones and Certain Deformities appearing at Adolescence and their Relation to Rickets. Late Rickets

GIVEN this general softening of the skeleton, associated with the loss of ligamentous and muscular support, many of the secondary deformities which occur in the bones can be shown to be produced by the mechanical effects of pressure. What form these deformations will take, depends on the direction in which the force is applied, and whether the child is attacked before the period of walking or afterwards. A vigorous, healthy child does not for long maintain the attitude of rest when it is awake. It shifts its position frequently and delights in action and in sudden movements. The rickety child habitually assumes and maintains this attitude of rest, the result being that the normal physiological attitude of rest tends to become fixed, and later to be exaggerated.

The femur is, as a rule, curved forwards and outwards throughout its length, an exaggeration of the slight normal curve of this bone. Before the child walks in the rachitic state, this curvature tends to be increased by the weight of the legs and feet as it sits on the mother's lap and the feet hang pendant. On walking, the weight of the trunk naturally tends to aggravate the curve. If an adult femur be examined, when the bone has undergone a process of induration and consolidation, and the disease has become arrested and partially cured, the appearances are very characteristic. The condition, in the great majority of cases, is symmetrical. Usually, the bone is hard and dense and may be heavier than normal. The growth of the bone in length is diminished, and this, with the bending of the shaft,



PLATE IV.

Rachitic femur (left) from a person of nearly adult age. Upper epiphyses completely united and the lower almost united. Upper and middle thirds of the bone are curved forwards and are laterally compressed. Linea aspera at this curved portion projects far backwards. Bone is hard and heavy. Surface of neck is rough as also is the surface of the lower third of the femur.—*Hunterian*.

tends to produce the shortened stature characteristic of rickets. The surface of the femur, especially in the upper portion of the shaft between the two trochanters, is frequently roughened, and there may be a similar roughening on the anterior surface of the lower third of the shaft. In the midst of this rough surface, above and between the condyles, there is often an area where the compact bone is clear and glistening, and when this is the case a similar area is present on the other femur, showing that the approach to symmetry is very close. The femur is frequently much flattened laterally, especially in the region of the greatest degree of curvature, and the anterior surface of the bone forms, as it were, the arc of a bow. Posteriorly, the concavity of the bone is filled in by a buttress of osseous tissue, thrown out to strengthen the bone where it is weakened by the arch. In the femur this is usually along the *linea aspera*, and a distinct ridge of bone fills up the concavity of the curve and forms the chord of the arc. (Pl. IV.) At other times this chord may not be seen on an examination of the external aspect of the bone. In the tibia, to make the compensatory strengthening support visible, a longitudinal section must be made, when it will be found that there is great thickening of the bone in its concavity, but this thickening takes place in the cancellous tissue of the shaft, so that the medullary cavity is much encroached upon.

Another characteristic deformity of rickets is an alteration of the angle at which the neck of the femur is set on the shaft. In the normal subject this varies with age. In the young child the neck of the thigh is so oblique that it forms almost a gentle curve from the axis of the shaft; in the adult the angle is an open one, about 125° ; as age advances the neck tends to drop and to approximate a right angle, and at the same time its compact wall becomes thinner and its cancellous tissue more expanded, so that there is an increased tendency to fracture of the neck of the femur in old subjects.

In the rachitic subject, the head and neck of the femur

are frequently somewhat small and slight, and the angle at which the neck is set on the shaft tends to be less obtuse than normal, that is, the rachitic bone tends to approximate in this respect the bone of aged persons. This is the natural result of the pressure of the weight of the trunk in the erect attitude, and is the condition to which the term *coxa vara* is applied. *Coxa vara*, however, is only said to be present when the deformity is sufficiently severe to produce symptoms. It may be a congenital condition, when it is quite unassociated with rickets and may be found in several members of the same family. Most commonly it is acquired and occurs at the period of adolescence, usually between the ages of thirteen and seventeen years. It may be unilateral or bilateral. While a tendency to this condition undoubtedly occurs as a result of rickets, *coxa vara* of a degree sufficient to produce symptoms is much less common than might be anticipated, considering the frequency with which the deformity in a mild form is seen in the rachitic femur. Fiorani first described this condition as occurring in fifteen cases of rickets, in 1881,* and the deformity is now well recognised.

Hoffa has seen it as early as eighteen months.

Whitman, in an analysis of seventy-two cases, found that, as regards the age of incidence, they were grouped as follows † :—

Over 17 years	...	...	...	...	6
Adolescents, 12-17 years	...	...	...	...	40
Later childhood, 5-11 years	...	...	...	...	23
Early childhood, less than 5	...	...	...	...	3

In about one-third of these cases there was a distinct history of rachitis. Outward curvature of the shaft is sometimes compensated by a downward direction of the neck. In the rare intractable cases, which do not recover spontaneously, the usual symptoms of *coxa vara* appear, viz., shortening of the limb, rotation outwards of the limb and eversion of the

* "Sopra una forma speciale di zoppicamento." Gazz. degli ospedali. 1881.

† "A Treatise on Orthopædic Surgery," by Royal Whitman, London, 1919.

foot, and adduction associated with limitation of abduction. The great trochanter is prominent, partly due to elevation of that process above Nelaton's line, and partly to muscular atrophy. Its incidence is apt to be associated with pain, and a limp or a waddling gait. The diagnosis is, as a rule, made on X-ray examination. Hoffa states the diagnosis between the congenital and rickety forms can be made out from the direction of the epiphysial line between the head and neck of the femur. In the rickety form it is oblique, while in the congenital form the direction is vertical. Spontaneous cure may generally be anticipated in rickets. The treatment of coxa vara in rickety cases is usually associated with the treatment of the other deformities in the limb, such as genu valgum, or curving of the tibia, leaving the coxa vara to right itself. Occasionally, in early infancy, individual cases benefit by forcible abduction, the limb afterwards being retained in the position of extreme abduction. In rare cases, linear osteotomy of the shaft, or the removal of a wedge of bone at the level of or below the trochanter minor may be required, when the deformity is severe and persistent.

The tibia and fibula frequently give way at a very early date. One of the early signs in connection with the tibia is the swelling which takes place at the lower extremity in the region of the epiphysial line, just above the malleolus. This is usually more marked on the tibial side, but the fibula may be similarly swollen, and the characteristic knotting just above the malleoli, with the tumefaction of the wrist, forms a very characteristic sign of the developed rachitic state. These swellings are not, as a rule, apparent so early as the beading of the ribs. Most commonly it is first appreciable from the twelfth to the eighteenth month, and the characteristic curving of the tibia is noticed somewhat later. In patients belonging to the hospital class, the bending of the tibia is usually noticed about the age of two years, or a little afterwards. Naturally, the children of better-class parents are brought to the surgeon at an earlier date than those of the poorer class. As a rule, the deformity commences at a much earlier age. Even before the child begins to walk,

the normal curvature of the tibia outwards tends to be exaggerated by the child sitting cross-legged, so that the outer malleolus bears on the floor. The characteristic curve is outwards and forwards. The outward curve is very constant and often very pronounced, and is most commonly seen at the junction of the lower and middle thirds, though it sometimes occurs in the upper third. As in the femur, there is usually flattening of the bone from side to side, resulting in the production of a knife-like edge. The forward curve most commonly affects the lower third of the bone or the junction of the lower and middle thirds, and the sabre-like edge of the tibia in this region is a sign pathognomonic of rickets.

On rare occasions the tibia may give way so as to produce a curve inwards. The fibula follows the changes in the tibia. Congenital syphilis may also induce bending of the tibia, and may give rise to some difficulty in diagnosis. As a rule, the rachitic curve appears before the third year; in congenital syphilis it may appear at any time up to the ninth year. In syphilis the curve is usually purely anterior, and the crest of the tibia is smooth and rounded, while the surfaces of the tibia are convex. In rickets, on the other hand, the convexity is usually antero-external and the edge of the tibia sabre-like, while the surfaces of the bone are either flat or concave. Frequently, the bowing of the tibia and fibula is associated with flat-foot, but genu valgum does not, as a rule, co-exist with it. Slight degrees of bow-legs are exceedingly common and generally tend towards spontaneous cure.

Genu recurvatum, in which the knee is habitually over-extended, may be found associated with many conditions such as club-foot, infantile paralysis, and deformities of one limb, but is especially common when the muscles and ligaments are relaxed, as in rickets. In children with loose joints a slight degree of over-extension is very common, and may be combined with a varying degree of knock-knee. In an interesting paper on adolescent or late rickets, Mr. Clutton shows an excellent X-ray photograph of the con-

dition, where the deformity is produced by curvature of the lower end of the femur with the convexity forwards, and of the upper end of the tibia with the convexity backwards. These changes are produced by an overgrowth in the neighbourhood of the epiphysial line, which, as is usually the case, is more marked on the diaphysial side of the epiphyses. In some cases the tibia alone shows the characteristic curve and, in slighter cases, genu recurvatum may simply be the result of the relaxation of the ligamentous and muscular supports of the joints without actual curvature of the bones.

In the upper limb the most characteristic sign of the rachitic state is the enlargement of the wrist, which takes place especially over the expanded lower end of the radius. As a rule, there is a furrow between the wrist and the hand. The shafts of the ulna and radius tend to show a slight curve, the convexity of which is backwards. This condition is most marked near the wrist and is simply an exaggeration of the normal curve of these bones. Later, in the sitting posture, the child throws part of the weight of the body on the arms, and as a result of the pressure both bones are apt to become somewhat twisted and curved outwards, especially in the neighbourhood of the wrist.

The rickety hand is relatively long and slender. Koplik described a beaded condition of the fingers, which he attributed to thickening of the shafts of the phalanges, so that the shafts of the bones were greater in circumference than the ends of the bones near the inter-phalangeal joints.* This appearance, however, as was pointed out by Siegert,† is rather due to the elongation and narrowing of the joints and the adjacent parts, owing to relaxation of tendons and ligaments, which leaves the middle of the phalanges relatively but not actually enlarged.

Frequently the humerus is but little deformed, and the epiphysial enlargement is much less marked at the elbow

* "The Rachitic Hand," by Henry Koplik. *Archiv. of Pediatrics*. Vol. XXI, 1904.

† Siegert: "Verhandl. d. Gesellschaft f. Kinderheilk." (Cassell), XX, 1903, p. 240.

than at the wrist. The shaft may be somewhat curved outwards and forwards, as in the femur. Later, the humerus tends to be bent outwards at the insertion of the deltoid, due to the weight of the arm acting on the softened bone when it is raised to a horizontal position by that muscle.

The scapula is apt to be somewhat swollen and softened, especially along its borders, though it is frequently unaffected. The clavicles are often markedly affected. As usual, the characteristic bending of the bone is an exaggeration of the normal curvature. The inner two-thirds is curved forwards more than is normally the case and is also bent somewhat upwards. This is most marked just outside the attachments of the pectoralis major and the sternocleido-mastoid muscles. The second curve is backwards, near the articulation to the acromion process, and the characteristic projection of the acromial end of the clavicle is often a very marked sign in the shoulder girdle of the rickety child. These curves are apt to be especially marked, owing to the force brought to bear on the clavicle when the weight of the trunk is thrown on the upper extremities.

Three deformities in the lower limbs have been mentioned, coxa vara, genu recurvatum, and genu varum, all common conditions which, however, are but incidents in the progress of the disease, and do not, as a rule, call for operative measures, in so far as they show a strong tendency to natural cure. Three conditions—scoliosis, genu valgum, and flat-foot or pes valgus—are very directly associated with rickets, and are important in that they often demand direct surgical treatment, and are the common deformities for which children are first brought under medical care. Each of these conditions may arise during the active stage of the disease, that is, in the first three or four years, and may even appear before the child learns to walk, but by far the greatest number of cases originate during the period of adolescence, and at the time of occupational strain, from twelve to eighteen years of age.

As with most rachitic deformities, several factors are concerned in their production, and these may be placed

under four headings : (1) increased strain due to the limbs having to support an excessive weight ; this agent is specially operative at the time of occupational strain, after school age, when continuous work is first undertaken ; (2) diminished resistance, due to the softened condition of the bones ; (3) loss of muscular tonicity and power. This third factor is of great importance, as has already been seen in speaking of abdominal tension, and not sufficient allowance has been made for it in the production of morbid states. The authority of Sir William Jenner is largely responsible for this. In his celebrated work on rickets, he discounts the effect of muscular action. "In excluding muscular action," he states, "from all direct share in the production of curvature of long bones, I am, so far as I know, unsupported by any authority." Now the action and interaction of opposing muscles is of the first importance in the development of the long bones, and is largely responsible for the very shape and nature of the surfaces of these bones, and when these are thrown out of action in varying degrees in the young infant, this loss of action greatly affects the development of the bone ; (4) the irregular thickening of the layer of cartilage which lies between the diaphyses and epiphyses of the long bones. This factor may in itself determine certain deformities, such as genu valgum, before the child learns to walk. The thickening may be considerably greater on one or other side of the joint, and this, with the increased formation of osteoid tissue which takes place as the result of the exaggerated growth of cartilage, tends to deflect the limb away from the side of greatest thickening.

The reason for the occurrence of genu valgum in one patient and of genu varum in another has been much discussed. Normally, the axes of the femoral shafts converge slightly towards the knee, so as to form, on the outer side, an angle of 165° with the long axes of the tibia. It may, therefore, be said that a slight degree of knock-knee is natural, and it can readily be understood that, if there is a bias in that direction when the child begins to walk, the natural tendency will be for the defect to become

exaggerated. But, as a matter of fact, the condition of genu varum and bow-legs are more common than knock-knee. Sir William Arbuthnot Lane, who has done much to re-introduce the old Cartesian mechanical theory in the explanation of morbid processes, believes that the determining factor is the position assumed by the lower extremities in the attitude of rest, while the child is in the erect attitude.

Put concretely, it depends on whether a plumb-line dropped from the head of the femur tends to fall to the inside or to the outside of the knee. Abduction of the foot, Lane points out, is the position of rest in the erect posture, while that of adduction is the attitude of activity. Abduction is the position habitually assumed when muscular activity is poor.* The rickety child tends to stand with both hips and knees flexed through an angle of 10° to 20° . If the heels are in apposition, and the inner margins of the feet include a right angle, the plumb-line falls considerably inside the centre of the knee joint, and most of the superjacent weight is transmitted through the internal condyle, and the patella tends to be displaced inwards upon the internal condyle. The bones, therefore, become deviated outwards at the knee and genu varum results. If, however, the child retains its lower limbs in such a position that the inner margins of the feet are parallel, so that the toes point directly forwards, the plumb-line falls outside the central point of the knee, and the weight is chiefly transmitted through the external condyle, and the outer tibial tuberosity and the bones at the knee are displaced inwards and forwards, producing rickety knock-knee.

Such an explanation applies to many cases but by no means to all. Both genu varum and genu valgum are quite common before the child assumes the erect attitude, and before the weight of the body is imposed on the two columns which support it in walking. *In utero* and at birth the limbs of the child are naturally bowed outwards. There is a general

* "A Brief Statement of the Causation of Several of the Simple and Rachitic Deformities that Develop during Young Life," by W. Arbuthnot Lane. *British Medical Journal*, 1889, Vol. I, p. 174. "Guy's Hospital Rep." 1883, Vol. XI.

curve from the hip to the ankle, more obvious below the knee. At the third or fourth month the healthy child, when lying on its mother's knee, loves to stretch the two limbs out, and gradually the tibiae become closely applied and run parallel to each other. This muscular tension is of the greatest value in moulding the shape of the limbs and in keeping the joints well knit. In rickets, the tone of the whole limb is affected by the loss of muscular action. Not only are the muscles soft and flabby, but the ligaments which support the joints are lax and long, allowing easy separation of the joint surfaces. The bones tend to retain the outward curve longer than normal.

When the rickety child sits up, and it must be remembered that the act of walking is considerably delayed, so that the sitting and crawling period tends to be unduly prolonged, the favourite attitude is sitting on the floor with the knees bent outwards and the legs drawn up towards the body. Frequently, the legs cross near the ankle. Often the hands are placed on the floor, so that the weight of the body is partly borne on the arms. In this position there is a marked tendency to separation of the external condyle of the femur from the articular surface of the external tuberosity of the tibia, and at this early period the two joint surfaces may easily be separated passively and may be brought together again with an impact. While the pressure is diminished on the outer side of the knee, there is increased pressure between the internal condyle and the articular surface of the internal tibial tuberosity. There is unnatural growth taking place in the epiphysial layer of cartilage in both the femur and the tibia, usually sufficiently marked to be visible to the naked eye on section. This growth in thickness is irregular, and in the cross-legged and sitting posture, owing to diminished pressure, tends to be greatest on the outer side of the bones, and the formation of new osteoid tissue is also greater, leading to an enlargement of the external condyle. Between the internal condyle and the inner tuberosity of the tibia the bone is compressed and the growth of cartilage

is relatively diminished, while the internal condyle becomes flattened, and may become very markedly so if the condition becomes exaggerated. If now the child struggles on to its feet while the bones are still soft and yielding, a bias has been given to the direction in which deflection will occur, and the weight of the body increases the bowing outwards. This is especially likely to happen if, before assuming the erect attitude, the child shuffles along the floor in the sitting posture with the aid of the hands, while the outer malleoli bear upon the floor.

If, on the other hand, the weak rachitic child crawls on the hands and knees, as it not unfrequently does for a prolonged period, with the inner malleoli bearing on the floor, the reverse action takes place. There is a tendency to separation of the inner condyle from the internal tuberosity, leading to diminished pressure and increased growth, while there is increased pressure and diminished growth on the outer side. At the same time, the internal lateral ligaments of the knee become unduly stretched. Normally, the inner condyle of the femur is fully half an inch lower than the outer in the adult when the bone is placed perpendicularly, but when the bone slants, as it naturally does, both condyles are on the same level. In the crawling position in rickets, the growth of the internal condyle is exaggerated, while that of the external condyle is diminished, and a condition of genu valgum is produced, which increases when the child assumes the erect attitude. The increased growth of the condyles chiefly affects the diaphysial side of the cartilage, and in the rickety form of knock-knee the femur is chiefly, and may be exclusively, at fault. When genu valgum and genu varum develop before the child walks, the epiphysial overgrowth is the important factor in determining the condition, and when the child walks it is still of importance. It will be readily understood that a very slightly increased unilateral overgrowth towards the internal or the external condyle may be sufficient to give the bias which will determine the deflection to one or other side when the child walks.

Flat-foot is a deformity which not infrequently follows as a result of rickets. It is a common complaint that the ankles are weak in the young rachitic child. The foot may constantly turn over in walking and there is frequently undue mobility at the ankle. The tibialis posticus, the tibialis anticus, the long flexors of the toes and the short flexors on the sole of the foot are deficient in tone. As the muscles tire, the weight of the body tends to be thrown on the ligaments, which become relaxed and weakened. The attitude of abduction, which is the attitude of rest, persists, and after a time becomes fixed. The posterior division of the tarsus, consisting of the os calcis and astragalus, is rotated inwards and downwards, while the part of the foot in front of the mediotarsal joint is rotated downward and outward in the direction of abduction. In such a case the arch may never form properly, and if already formed it may become depressed. Such a condition in the young child is frequently present without much pain, and, as a rule, though it may be recognised that the child has weak ankles, symptoms of flat-foot do not supervene till the period of adolescence. Whitman* gives the following analysis of 1,000 cases, showing the rate of incidence of flat-foot at various periods :—

Age of Incidence.	Males.	Females.	Total.
10 years or less	68	30	98
10 to 15 years	112	87	199
15 to 20 "	144	83	227
20 to 25 "	94	53	147
25 to 30 "	68	41	109
More than 30 years	132	88	220

Seeing then that flat-foot does not usually occur till the age of adolescence, and that the active stage of rickets belongs essentially to the first two or three years of the child's life, the question arises as to the manner in which the disease is responsible for the production of this late deformity.

* "Orthopædic Surgery," Whitman. London, 1919.

In the same way scoliosis and knock-knee, though, as has already been noted, they frequently occur in the young rachitic child between the ages of one and four years, are essentially deformities which appear during adolescence.

There are two periods during which bony growth is exceedingly active and in which deformities of the bones are especially liable to occur. The first period is from birth up to the age of three or four years, and the most active morbid conditions which seriously affect the skeletal growth at this early period are syphilis and rickets. Adolescence is the second period of weakness, and may be considered as extending over a lengthened period, from the age of twelve years up to seventeen or eighteen years. During this period the growth of bone, which has been relatively quiescent, again takes on a new activity. Other factors are of importance at this time. The sexual functions develop at this period; a considerable degree of mental strain is often imposed on the child in the closing years of its school life, and, what is exceedingly important, when the child leaves school at the age of fourteen, it is for the first time subjected to serious occupational stress.

In the first period rickets is known to be active, and it can be readily understood that bony deformities result. The association of this disease with the deformities produced during the years of adolescence and later is, however, less readily comprehended.

This raises the question of late rickets. As long ago as 1860, Sir William Jenner referred to a case of rickets arising in a girl of nineteen years.* Dr. F. G. D. Drewitt showed a boy, aged ten years, to the Pathological Society of London, in November, 1890. The boy died two years afterwards, and the post-mortem examination showed that the process was undoubtedly one of true rickets.† Since then many cases have been shown, and although the disease, in the form in which it is met with in the young infant, is not common at

* *Medical Times and Gazette*, Vol. I, 1860.

† "Transactions of the Pathological Society," Vol. XXXII.

this late period, it has been shown to be more frequent than was generally supposed.*

There is a considerable difference between the condition of the skeleton in early infancy and that which exists at adolescence. At the earlier period the long bones are membranous tubes supporting layers of young bone arranged in Haversian systems, the greatest thickness of the bone being at the centre of the shaft and rapidly diminishing in thickness towards the extremities. The resulting bony and membranous tube is hour-glass shaped, and each end is capped by a cartilaginous pad in which the chief growth in length of the bone takes place. In the later period of adolescence the bone has already assumed its adult form, and even were the child exposed in the same degree as in early infancy to the conditions which produce rickets, which is improbable, the florid type of the disease is much less likely to occur. The epiphyses, however, have not yet joined the shaft of the bone and the cartilaginous layer is still present, and X-ray examination of many cases has shown that active rickets does occur at this time. But these cases are relatively infrequent, and the acute form of the disease is not sufficiently common to explain the large number of deformities which arise at this period.

Ogston, of Aberdeen, holds that knock-knee, flat-foot and scoliosis are the most common deformities arising from adolescent rickets, and flat-foot, he believes, is seldom due to anything else but rickets.†

The question arises whether this is a new disease or a recrudescence of the rachitic state which has persisted since infancy.

In considering the effect of rickets on the health of the community, it is of the first importance to remember that while rickets is essentially a curable disease, it is, at the same time, a disease which retains a tenacious hold of the

* "Adolescent or Late Rickets," by H. H. Clutton, *Lancet*, Vol. II, 1906, p. 1268. "A Case of Recrudescent Rickets," by Robert Jones, *Liverpool Medico-Chirurgical Journal*, No. 30, January, 1896, p. 480.

† "The Surgical Treatment of Rickets," by Alex. Ogston, M.D., C.M., *British Medical Journal*, Vol. II for 1888, p. 1148.

individual, and that the recovery is, in the great majority of cases, only partial. The adult stage of the rickety infant is permanently handicapped in many ways. The youth is apt to be short and stunted in his growth, or he may be tall and thin and weedy. He is likely to be long-chested with stooping shoulders, and to have a sallow complexion. Such individuals lack the spring of healthy youth. The muscles and ligaments are still weak and relaxed, and the joints show undue mobility. These are the children who develop scoliosis at school, and flat-foot and knock-knee when the extra demand on their energy is made by adolescence; or these conditions may develop somewhat later, when occupational strain comes to bear on their enfeebled constitution. In the late war, military service was the test which revealed the existence of this large class of debilitated individuals, which forms to-day a heavy charge on the community.

As has been shown, a reparative process occurs in the bone of the young rickety subject, whereby it is consolidated and may be rendered unduly dense and heavy. In such a condition florid rickets is not likely to occur, but in the majority of cases this reparative process is imperfect and the bone remains unduly light and capable of further giving way when undue strain is placed upon it.

Not infrequently the three deformities, scoliosis, knock-knee and flat-foot are associated together in the same subject. At other times, the first part of the support to give way is the foot, and flat-foot develops, to be followed by genu valgum at a later date.

It is not claimed that all three deformities are necessarily rachitic. If a boy of fourteen or sixteen years is placed continuously at heavy work, such as a bricklayer's labourer, or if a girl be allowed to carry heavy weights before the osseous and ligamentous structures of the spine and the lower limbs are sufficiently developed and consolidated, failure of some part of the skeletal support is likely to occur. But this is by no means the most important factor. Among girls, scoliosis is met with much more

frequently in the well-to-do than in the labouring classes of the community.

Rheumatism is another condition which may produce any of these deformities, apart from rickets ; but it is not a common cause. In young adults chronic synovitis, by leading to weakening of the ligamentous structures, occasionally in itself leads to the development of knock-knee. But, allowing for all such conditions, the great majority of these deformities occur in connection with the rachitic state. The young adolescent does not assume faulty attitudes without reason ; the position of rest is sought and unduly maintained because the child's muscles and ligaments have been weakened by present or pre-existing disease.

Three propositions then may be stated with reference to the occurrence of late rickets, viz. : (1) that rickets may arise *de novo* at puberty, though this is not common ; (2) that a recrudescence of a previously existing disease is much more common, and that adolescent rickets is practically the same disease as the infantile form, modified in some respects by the age of the patient and by the tendency to partial recovery which has taken place ; (3) that without a fresh outbreak of the disease, many of the weak and debilitated subjects of early rickets first break down when the extra strain of adolescence and continuous occupation is imposed upon them ; that is, the recovery from the disease has only been partial and a protracted weakness of the muscles, ligaments, and bones has been left behind, which leads to failure at the first period of stress.

To this last class belong by far the greatest proportion of these failures in the supporting structures which are so liable to occur at adolescence.

CHAPTER XII

Deformities of the Thorax in Rickets

IN the rachitic infant the thorax looks small in comparison with the large head and the enlargement of the abdomen. Normally, at birth, the circumference of the chest forms almost a perfect circle, and the antero-posterior diameter and the transverse diameter are equal. Towards the end of the first year the transverse diameter exceeds the antero-posterior, but the somewhat cylindrical shape is retained till the end of the second year.

About the fifth year the permanent shape is attained, the proportion of the transverse to the antero-posterior diameter being as 7 is to 5.

In the young infant there is not much movement of the ribs when the child is breathing quietly; the respiration is chiefly diaphragmatic, the abdomen being protruded slightly with each inspiration, the elastic recoil of the abdominal walls aiding the act of expiration. The child in health breathes more quickly than the adult; in rickets the respiratory act is apt to be much hastened, and may, without any affection of the lungs, reach from forty to eighty respirations per minute.

To this quickening of the respiratory act the term *polypnœa* has been applied. The respiratory rhythm is frequently altered in rickets. Instead of a long inspiration being followed by expiration, and this by a pause, as in the adult, there is often a short expiratory grunt followed by an inspiration, and that by a pause.* In place of being a smooth modulated act, the respiratory rhythm becomes jerky and spasmodic—a factor which has an important

* "On dirait, suivant l'expression de Rilliet et Barthez que l'enfant crache son expiration." Marfan, *loc. cit.*, p. 260.

bearing on the production of deformation of the chest wall Hutchison * suggests as a reasonable explanation of this inversion of the rhythm that it facilitates freer oxidation of the blood, for the pause after inspiration means that the lungs are kept full of pure air for a much longer period than by the normal method.

Asymmetry of the chest is a common defect in rickets, such as a tendency to flattening of the left apex with a projection of the chest wall to the right side of the lower part of the sternum where it meets with the true ribs. This distortion of the chest is usually the result of a slight lateral curvature of the spine, and indeed the slighter forms of scoliosis can often be diagnosed more easily from the front than by an examination of the spine itself; which apex is flattened and which shoulder is elevated varies with the form of lateral curvature present. It is noteworthy that impairment of the resonance at one or other apex with flattening is in children more frequently due to distortion of the chest than to tubercle.

Another of the slighter deformations of the chest is an elevation of the manubrium sterni at the level of the sterno-clavicular joints, so that the whole chest seems as if it were tilted forward and raised. This is associated with a flattening of the chest in the sub-mammary region, as if the chest had been squeezed in by two hands placed on the infra-mammary regions, resulting in a pressing forward of the upper part of the chest and the upper portion of the sternum. This is a deformity which is commonly seen in long-chested delicate adolescents and may persist throughout life.

Beading of the ribs is an early and very constant sign of well marked rickets. This consists in a nodular swelling at the junction of the cartilage with the bony part of the rib. As a rule, the beading is more angular than globular, and is usually much more marked on the surface of the rib which is towards the pleura than on that which is external, where it may easily be missed by the examining finger.

* "Lectures on Diseases of Children," by Robt. Hutchison. London, 1906.

A very common result of pressure of these rachitic nodes is the so-called "white patch" on the visceral surface of the pericardium. This is usually situated on the left ventricle a little above its apex, just where the heart impinges on the nodule of the fifth rib.*

As already noted, not all nodular enlargements of the ribs are rachitic. In scurvy very definite enlargement of the costo-chondral articulation is likely to develop. Scurvy, though usually associated with rickets, is by no means necessarily so. It not infrequently occurs in children who, apart from the error of diet which is responsible for the onset of scurvy, live a healthy life much in the open under conditions which are not likely to produce rickets. Rickets is essentially a disease of the poor slum-dweller; scurvy is frequently a disease of the well-to-do, where the child is kept rigidly to some proprietary food which is deficient in the anti-scorbutic factor. The histological appearances, as has been shown, are quite different from those which appertain in rickets.

In considering the production of rachitic deformities of the chest wall four factors are of great importance: (1) atmospheric pressure; (2) great softening of the bony portion of the rib; (3) weakness of the muscles of inspiration due to (a) the general debility of rickets, (b) loss of purchase on the softened bones; (4) over-action of the diaphragm.

Jenner was the first to point out clearly the great and predominant part played by atmospheric pressure in the production of these deformities, but in bringing forward this theory there can be little doubt that he discounted too much the effect of the loss of general muscular action and tone, and in the case of the diaphragm, the relative over-action, and still more important, the disordered action of this muscle.

In ordinary nasal breathing in health, when the diaphragm contracts and the ribs are elevated by muscular action, air rushes in through the glottis and expands the

* "The Wasting Diseases of Children," by Eustace Smith, London, 1878, p. 145.

lungs, allowing them to follow the expanding chest wall. In rickets, owing to the loss of muscular power and the softening of the ribs, the muscles have no power to pull up and evert them, and the tendency to negative pressure produced by the contraction of the diaphragm, gives full play to the atmospheric pressure which tends to crush in the chest wall all round. The ribs give at their weakest part, and as a result a longitudinal sulcus is formed just outside the beads at the costo-chondral junctions.

In the rachitic child, and especially in the mouth breather, the entry of air into the chest is defective, and the softened ribs, unsupported by internal pressure, are not able to withstand the pressure outside. The result is, that if the chest be looked at from behind, the ribs are much flattened. As they leave the spine they pass horizontally outwards and then bend sharply forwards at the angle, passing forward and inwards to join their cartilages.

In cross section the chest assumes a triangular form, the two posterior angles being formed by the angles of the ribs and the anterior angle being formed by the sternum.

This gives rise to the appearance which Glisson describes so accurately and which he likened to the prow of a ship, the condition being commonly known as "pigeon-breast." The bending forward at the angle of the rib is often very acute, and it is quite common to find a green stick fracture on one or more of the ribs at this situation and often on both sides. This may be due entirely to atmospheric pressure, but is probably more frequently due to handling the child in lifting it. These fractures, like all fractures in rickety children, heal quite readily.

The longitudinal groove on the antero-lateral surface of the chest, lying just outside the nodules on the ribs, extends from the second or third rib above to the ninth or tenth rib below. It passes downwards and outwards. The groove varies on the two sides, tending to be shorter on the right side, owing to the liver supporting the ribs, and to be shallower on the left side, at the level of the fourth and fifth ribs, owing to the subjacent heart. This deep groove on

either side of the sternum tends to thrust the sternum forwards, producing the different forms of "pigeon-breast."

Another groove commonly seen in rickets, which is frequently known as Harrison's sulcus, is a transverse constriction beginning at the xiphisternum and passing outwards and slightly downwards just below the sixth rib. As a rule, it does not reach as far as the mid-axillary line. It is mainly due to atmospheric pressure driving in the softened ribs, on the one hand, and the liver, stomach and spleen helping to bulge the lower ribs out, on the other. In many of these cases, especially when the diaphragm acts spasmodically, the muscle can be seen to draw in this sulcus forcibly with each inspiration. An inverted action of the diaphragm takes place, and instead of the diaphragm obtaining its purchase from its parietal origin and pulling on the central tendon so as to flatten the diaphragm and drive the abdominal wall forwards, the muscle contracts over the inert abdominal mass and exercises traction on its origin more forcibly than on the central tendon. As a result the lower part of the thoracic parieties are moulded as it were over the abdominal contents, while the lower border of the chest wall is everted and lipping takes place along this margin.

Most of the more marked forms of pigeon-breast are associated with obstruction to the free entry of air, and this obstruction, in the majority of cases, is due to adenoids. But the same condition is frequently developed in the mouth breather, who does not suffer from adenoids.

A rarer variety of chest deformity is observed where the sternum, instead of being thrust forward is depressed and drawn in, as it were, towards the spinal column. The whole length of the sternum may be sunk in, producing the gutter-shaped chest (*thorax en gouttière*), but more commonly the lower part of the sternum is markedly retracted, forming the funnel-shaped chest (*thorax en entonnoir*—*Trichterbrust*).

In Barlow's disease, there is a great and sudden weakening of the chest wall, due to the acute destructive changes which

take place at the costo-chondral articulations. This rapid weakening tends to result in a marked sinking in of the whole length of the sternum, producing the gutter-shaped chest. As long ago as 1894, Barlow stated : " During the development of this disease the sternum, with the adjacent costal cartilage and a small portion of the contiguous ribs, seemed to have sunk bodily back *en bloc*, as though it had been subjected to some violence which had fractured several ribs in front and driven them back. This curious appearance, taken in conjunction with the sub-periosteal and other hæmorrhages, is said to be diagnostic of the disease." Barlow's disease is an acute condition, and the severity of the changes leads to this sudden giving way of the front of the chest wall. In the slower process of rickets there is not the same tendency to the formation of the gutter-shaped chest, although it may occasionally be seen as a result of severe and continued spasm of the glottis associated with embarrassed action of the diaphragm.

When the rickety infant is attacked with whooping cough the prognosis as regards recovery is usually very gloomy. Death is exceedingly likely to supervene from broncho-pneumonia associated with collapse of the lung. In this condition the over-action of the diaphragm and the spasm of the glottis are apt to lead to marked retraction of the lower part of the chest, especially of the lower part of the sternum. If recovery takes place a true funnel-shaped deformity is not infrequently left behind, in which the xiphisternum and the lower part of the mesosternum are deeply retracted.

The method of production of the funnel-shaped chest has given rise to much discussion and many varied opinions. The congenital form, which may affect any portion or the whole of the sternum, and the variety due to occupational pressure, as in the well known cobbler's hollow, have no specific connection with rickets and need only be mentioned.

In normal respiration there are several factors which are accurately correlated to each other, viz., the strength of the thoracic parietes, the opening of the larynx, and the action of the diaphragm and of the inspiratory muscles.

Normally, the contraction of the diaphragm tends to produce a negative pressure within the chest, and the elasticity of the lungs is exactly met and overcome by the inrush of air through the glottis. The balance, however, is easily upset, for if the child sobs violently and contracts the diaphragm with abnormal rapidity and force, the most flexible part of the thoracic wall is drawn in during inspiration. If the orifice of the glottis be narrowed, the recession of the lower part of the chest wall becomes marked and may be very distressing, as in laryngismus stridulus.

The funnel-shaped chest is particularly likely to be developed in the rickety state, when there is a spasmodic contraction of the diaphragm associated with narrowing of the glottis. Normally, the xiphisternum and the cartilage of the fifth, sixth, and seventh rib cartilages are braced up by the insertion of the rectus abdominis into their outer surfaces. In rickets this muscle tends to be peculiarly flaccid and inert, and this support is lost. The diaphragm, it must be remembered, is a muscle acting between two mobile resistances, the thorax on the one hand, and the abdominal contents on the other, each of which is liable to many and frequently recurring variations. The contraction is capable of producing a double effect on the thorax or on the abdomen, according to the variations which occur in the resistance of these two factors.

Thus, in rickets, when the muscle contracts over the inert and immobile abdominal mass the central tendon becomes, as it were, the fulcrum of the lever and the force of the contraction acts on the chest wall, so that the soft cartilages and ribs are drawn markedly in over the liver, spleen and stomach, deepening Harrison's sulcus. Normally, the anterior fibres of the diaphragm, which are directed more horizontally towards the central tendon, oppose the forward motion of the sternum, but in cases where there is prolonged over-action of this muscle, as in rickets, the inverted pull of these fibres may very markedly retract the xiphisternum. Occasionally the funnel-shaped depression

can be seen in the actual process of formation, recurring with each inspiration and flattening out during repose. Prolonged bronchitis may lead to excessive and spasmodic action of the diaphragm, especially in the inverted form of respiratory rhythm already spoken of, where the child grunts out the expiration and follows this with a prolonged inspiration and then a pause.

Jenner taught that in all these cases the cartilages were softer than the bony parts of the ribs, and were driven backwards by atmospheric pressure. This is difficult to reconcile with the direct pull on the thoracic parietes so often seen in these debilitated children, and with the fact that in these severe rickety cases the bone is often softer than the cartilage.

Certain difficulties in the diagnosis of chest diseases may arise as the result of rachitic deformations. It has already been pointed out that in the flattening of the apex associated with lateral curvature, dullness may be produced which bears no connection with tubercle. Again, in the rachitic subject acute disease of the lung may produce violent symptoms, very often out of proportion to the actual extent of the disease.

Where, as usually happens, the ribs are, as it were, moulded over the heart, the action of the heart may from very slight causes act very violently, and the sound and impulse may be so diffuse as to give rise to the impression that there is serious organic disease where none exists. Rickety distortion of the skeleton may also give rise to abnormal conditions of the blood vessels closely simulating aneurism. It is not uncommon in cases of scoliosis to find abnormal pulsation between the second and third ribs on the right side of the sternum, suggesting the possibility of an aortic aneurism, and this mistake has not infrequently been made.

This abnormal pulsation, visible either to the right or to the left of the sternum, simulating aneurism, may be due to deflection of the aorta consequent on rachitic malformation of the chest.

Balfour describes several such cases, and believes that they are by no means uncommon.* If the possibility of such a condition is kept in view, the grave error of stating that a patient has a serious disease, such as aneurism of the aorta, when in reality he is only suffering from a rachitic deformity of the chest, probably of little consequence, will be avoided.

* "Clinical Lectures on Diseases of the Heart and Aorta," by George Wm. Balfour, 3rd Edition, London, 1898, p. 386.

CHAPTER XIII

Deformities of the Spine and of the Pelvis associated with Rickets.

GLISSON derived the name rachitis, which he gave to this disease, from the fact that the spine was one of the chief parts of the body to suffer. Not that the spine is more markedly affected than other parts of the skeleton, but because it lends itself to deformations which are often permanent and ineradicable.

Antero-posterior curvatures of the spine.

The rachitic child is late in learning to walk, and for a prolonged period tends to assume a habitual sedentary position, in which the head and neck and thorax are bent forwards. The spine assumes a long curve with the convexity backwards, which culminates in a rounded projection at the level of the junction of the last dorsal with the first lumbar vertebræ. The anterior portion of the bodies of the last two dorsal and the first two lumbar vertebræ are compressed vertically and the fibro-cartilages project from between them. The vertebræ are still largely cartilaginous and are easily moulded, and there is a tendency to diminished growth of the anterior portion of their bodies in the concavity of the curvature, and to increased growth at the convexity. Not only are the bones soft but the ligaments and muscles which support the spine are relaxed. The weakest part of the spine is about the last dorsal vertebra. It is the centre of the spine and the centre of motion in the back, and is exposed to the powerful leverage of the vertebral column above and below it. The lumbar portion is

very flexible, while the dorsal, supported by its ribs, is comparatively rigid. The part of the spine which forms the greatest degree of convexity in rickety kyphosis is rounded and has not the angular appearance which is usually associated with Pott's disease. Usually, too, the deformity is easily reduced, and for a long time remains a faulty attitude rather than an actual deformity. About the third year the spine tends to recover and no trace of the condition may be left. Not infrequently, a certain degree of lateral curvature is associated with the kyphosis. In some cases the kyphosis does not develop till a later period. This may happen in the young child who has just begun to attend school, when the routine and confinement prove injurious. The remedy is plenty of exercise in the open air, good food, and a proper regulation of the time for study and for recreation.

It has already been noted, in speaking of the development of flat-foot and knock-knee, that long after the active rachitic process is over various sequelæ remain for many years, notably weakness of the ligaments and muscles and a degree of softening of the bones, allowing of bending and deformation of the various columns which support the weight of the body. This latent weakness is especially apt to show itself at the period of adolescence in those who have outgrown their stock of muscular and nervous strength. Round shoulders and arching of the back in the upper dorsal or cervico-dorsal region are exceedingly apt to develop. The head is held in advance of the body, so that the chin approximates the sternum. The chest is flattened and concave, corresponding to the rounded back which carries the shoulders forward, so that the arms hang away from the body. The scapulæ are apt to be somewhat winged and prominent. Frequently such conditions are associated with lateral deviation of the spine. In early cases the attitude of the young rickety child in the sitting posture, with the arched back, and the head, which the cervical vertebræ are too weak to support, thrown well backwards, forms a very characteristic picture.

When the rickety child struggles to its feet, the spine has now to adapt itself to the erect attitude. The head and shoulders tend to weigh the body forwards, and this may be counteracted by the production of forward bending of the spine, or lordosis. The hollow, as a rule, is in the lower dorsal and lumbar region, and by its means the weight of the head and shoulders is thrown backwards and the weight of the protuberant abdomen is counterbalanced. Except in severe and protracted cases, the kyphosis and lordosis both tend to correct themselves as the disease passes off towards the age of four or five years, and as the child gains strength as the result of exercise. No marked structural alterations, as a rule, occur in the vertebræ.

Lateral curvature of the spine, or scoliosis.

It is commonly stated that lateral deviations of the spine are less common in rickets than the antero-posterior curvatures. This is true if the study of scoliosis be limited to the period during which the child is suffering from active disease during the first two or three years of its life. But these deformities by no means represent the total influence of rickets in the production of spinal deformities. In the young child, scoliosis, if less common than the antero-posterior deformities, is of much greater importance, in that it tends to last much longer, and to lead to more or less permanent deformities. Scoliosis appears somewhat later than kyphosis, usually between the second and the fourth year. In the young infant it is frequently stated that the mother, as she carries the child in the sitting posture on the left forearm, tends to produce a curvature with the convexity towards the left. While this is possible, it is not a common factor in the production of scoliosis. In the young rachitic subject, the convexity of the curve may be directed either to the right or to the left. In the adolescent form of rickety scoliosis, the curve with the convexity to the right is the common variety. Slight degrees of lateral curvature in young children are of much more common occurrence than is generally supposed, and in early school life its presence is

often shown by the production of slight flattening at one apex with slight prominence of the lower ribs on the opposite side. This is due to early rotation of the trunk, and the presence of slight degrees of lateral curvature may often be more easily diagnosed from an examination of the front of the chest than of the spine itself. At the age of five years, these slighter forms of curvature may pass away and leave no trace, but, if at all marked, they not infrequently persist and may very slowly increase, or may begin to advance rapidly at the age of puberty.

Scoliosis in later childhood and during adolescence.

In well marked and permanent cases of lateral curvature, two deformities are to be noted: (1) a lateral deviation of the spine to one or other side of the median line; (2) a rotation of the vertebræ round a vertical axis. When the patient stands, the simple lateral curvature is most readily noted, but when the body is bent forwards and the back is viewed from behind, the torsion of the trunk becomes the prominent deformity. It is not the lateral inclination of the spine, as a rule, which induces the mother to bring the child for treatment, it is usually a "high" shoulder or a "high" hip that is first noticed.

The causes of lateral curvature of the spine are many and varied, but when all cases dependent on such direct causes as irregularity of the length of the limbs, infantile paralysis, diseases of the chest are excluded, and others definitely due to occupational stress of an exceptionally heavy nature, there remains a large class usually discussed under the heading of "scoliosis of adolescents," which is generally supposed to begin at puberty, but which has its origin at a very much earlier period. These children lack vigour and are much inclined to loll about. They are unable to bear any sustained fatigue, and when the stress of adolescence comes, the weak muscles, ligaments, and bones, are apt to give at the points of stress, and such conditions as flat-foot, knock-knee, and scoliosis are likely to supervene. Attacks of acute disease, chlorotic anæmia, tuberculosis, and

various other conditions may predispose to the production of these deformities, but by far the commonest and most important cause is the rachitic state in early infancy, which has left its mark in a profound debility and the weakening of the supporting structures of the skeleton.

For various reasons girls suffer more than boys. They are apt to be subjected for a longer period to the debilitating influence of a confined and unhealthy environment, and the demand made on their reserve of strength at the time of puberty is considerably greater than in boys. A much larger process of adaptation has to take place in the female skeleton at this period than in the male, and the likelihood of a breakdown is greatly increased.

While it is difficult to estimate the proportion of cases in which rickets is responsible for the production of scoliosis, the probability is that the larger proportion of severe and intractable forms are directly due to this disease.

Tubby has pointed out that scoliosis is very commonly associated in young adults with nasal obstruction and adenoids. The sequence of adenoids causing chest deformity in early childhood, with kyphosis at a slightly later period, say from six to ten years, followed by scoliosis at the age of puberty, is a very common one. Frequently the removal of enlarged tonsils and adenoids leads to a rapid disappearance of the deformity and an immediate improvement in the general health. As already stated, the high shoulder or hip, or prominence of the scapula, are the common conditions for which the mother seeks advice.

In the most common variety of scoliosis, the primary curve is present in the dorsal region with the convexity to the right, while there is a compensatory curve to the left in the lumbar region and often a slighter compensatory curve also to the left in the cervical region. The deformity produced by the twisting of the trunk, in a well marked case, is as if a hand had been placed on the right infra-mammary region in front and the other hand over the posterior surface of the chest in the region of the angles of the left

ribs, and firm and continuous pressure had been maintained. The result is that the angles of the ribs on the right side are drawn backwards, so that the angles become more acute than normal and project beyond the spinous processes. From this sharp angle the rib on the right side bends suddenly forwards. (See Fig. 4.)

On the left side the angle of the rib is much more open and the ribs take a much wider sweep, so that from the back this side of the chest is broadened and flattened. The right shoulder is high and the left is depressed, and usually the right hip is prominent while the left is flattened.

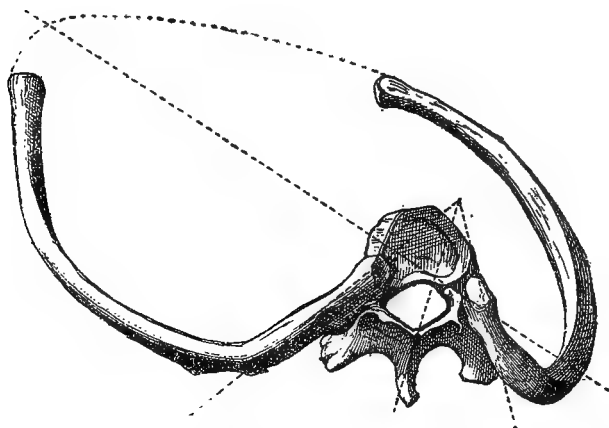


FIG. 4.—Illustrating the alteration in the shape of the ribs, and the deviation of the transverse diameter of the thorax.

Deformities of the pelvis associated with rickets.

It has already been shown that rickets is peculiarly dysgenic, in that it affects the young infant almost immediately after birth and continues to produce its evil effects during the period of most rapid growth, up to the end of the second or third year. From that time forward there is a marked tendency to recovery, but such recovery, even in comparatively mild cases, is only partial, and sequelæ are

left which produce far-reaching results, especially at periods of stress, such as puberty.

But rickets is extremely harmful to the young infant in another direction, and that is in its effects on the bony pelvis of the female, whereby it produces deformity of the passages through which the child has to pass, often endangering the life of the infant and increasing the risk of injury and of infection to the mother. It is well known that labour is more difficult and more dangerous, both to mother and child, in civilised communities than it is among savage people. It is also recognised that the more extreme degrees of dystocia are most commonly met with in large industrial communities. In England, degrees of deformity demanding Cæsarean section and craniotomy are comparatively rare, but in certain districts on the Continent they seem to be so frequent that these ultimate resources of the obstetric art have to be constantly employed.

In 1911, Amand Routh published a series of 1,282 cases of Cæsarean section in Great Britain, representing a complete list of all cases operated upon in Great Britain and Ireland by obstetricians living on June 1, 1910.* In 1,058 of these cases the indication for operation was pelvic contraction. In the great majority of cases these high degrees of deformity are due to rickets. The distribution of these cases is very interesting, and the small number found in Ireland and Wales as compared with the large number in Scotland is very noteworthy, indicating the comparative infrequency of the severer forms of rickets in these two countries. The distribution is as follows :—

England ...	...	...	...	841
Scotland ...	...	...	...	375
Ireland ...	...	...	...	53
Wales ...	...	...	...	13
				1,282

* "Cæsarean Section in Great Britain and Ireland," by Amand Routh. London, 1911.

The distribution in the various towns is also of interest, as indicating where the most extreme varieties of rickets occur. These are as follows :—

England—	London	...	...	...	383
	Manchester	...	...	...	155
	Liverpool	...	...	...	96
	Sheffield	...	...	...	92
	Leeds	...	...	...	38
	Birmingham	...	...	...	34
	Wolverhampton	...	...	...	15
	Newcastle	...	...	...	15
	Bristol	...	...	...	13
Wales—	Cardiff	...	...	...	13
Scotland—	Glasgow	...	...	...	304
	Edinburgh	...	...	...	59
	Dundee	...	...	...	9
	Aberdeen	...	...	...	3
Ireland—	Dublin	...	...	...	40
	Belfast	...	...	...	9
	Cork	...	...	...	4
					1,282

It is noteworthy that in Glasgow the number of cases is almost as great as that occurring in London. In Manchester the number of cases is much higher than in Liverpool, though the population of these two towns is approximately the same. Rickets is both less frequent and less severe in Liverpool, an advantage which it enjoys owing to its large river frontage on the Mersey. In Birmingham, with a population somewhat greater than that of Manchester, the number of cases is considerably less than a quarter of what it is in that city. In Dublin, Belfast and Cardiff, the number of cases is notably small.

It is difficult to get a true estimate of the frequency of occurrence of contraction of the pelvis in the general population. There are several varieties of deformity produced in the pelvis by rickets, but in all the essential feature is shortening of the conjugate diameter, that is, of the antero-posterior diameter at the plane of the brim of the true pelvis, which runs from the centre of the promontory

of the sacrum to the upper part of the posterior surface of the symphysis pubis. A pelvis in which this diameter is shortened is designated a "flat" pelvis, and this is the essential deformity produced by rickets. Normally, the *conjugata vera* measures $4\frac{1}{4}$ inches on the dry bony pelvis, or, allowing for the presence of the soft parts, 4 inches. When it is shortened to $3\frac{1}{2}$ inches (8.5 cm.) contraction is said to be present.

Winckel states that in Germany contraction of the pelvis is found in from ten to fifteen per cent. of all parturient women, and in Munich, where he was professor of gynaecology, he insists on the great frequency of rickety deformity of the pelvis, notwithstanding the fact that in that city, death carries off a large proportion of the rachitic children who, in other regions, increase to such an enormous extent the number of difficult labours from narrowing of the pelvis.*

In the absence of direct measurements of the pelvis, it is difficult to estimate the frequency of contraction, for in many cases with contraction labour is accomplished without undue difficulty. Systematic measurements have been conducted in Germany more frequently than elsewhere, and taking a diminution of $1\frac{1}{2}$ cm. to 2 cm., in an important diameter, as constituting a contracted pelvis, it is estimated that in Germany as a whole, 14 to 20 per cent. are to be thus designated. If the contraction were to be considered as being present only where serious dystocia resulted, the proportion would only be from 3 to 5 per cent.† Thus, in Vienna, among over 50,000 labours in the University Clinic, between 1878 and 1895, it was estimated to be present in 2.5 per cent., and at Queen Charlotte's Hospital, London, in 1,000 cases it was found in 4 per cent. Among women born in America contracted pelvis is rare, but among the alien population, and the negroes, high grades of contraction are not infrequently met with. In Australia, New Zealand,

* "A Text-book of Obstetrics," by Dr. F. Winckel. Translated by J. Clifton Edgar. Edinburgh and London, 1890.

† "The Principles and Practice of Obstetrics," by Joseph B. de Lee. Philadelphia and London, 1918.

and South Africa, contraction of the pelvis to a degree sufficient to interfere with labour is very rare.

Labour may be rendered difficult by changes in any one of the three factors concerned in labour, viz.: (1) in the powers, which include the uterus and the abdominal muscles; (2) in the child itself, such as increased size of the head in hydrocephalus, and faulty presentations; (3) in the passages, including changes in the soft parts, such as rigidity of the cervix, and in the bony pelvis, narrowing and deformation of the various diameters of the true pelvis through which the child must pass.

Rickets is the common factor affecting the diameters of the bony pelvis. There are several varieties of deformation, but in all, as already stated, "flattening" or diminution of the conjugate diameter is the essential feature.

Two factors are at work in producing these deformities—abnormality in the development of the bones, and the mechanical action of various forces upon the softened bones. As a result of the rachitic state, there is, in the pelvic bones, as in all the other bones of the skeleton, a tendency to stunted growth. The sacrum is broader from side to side and thinner from behind forward. The deformation of the pelvis begins while the child is as yet in the sitting posture, before it has learned to walk.

The weight of the body is transmitted through the spinal column to the sacral promontory, and thence to the iliac bones and the tuberosities of the ischii. Normally, the anterior surface of the sacrum is concave from above downwards and from side to side. In rickets the weight of the body causes the sacrum to sink forward, so that the promontory tends to approach the pubis. The concavity of the transverse curve is flattened out by the weight of the body acting on the softened bone. The upper part of the sacrum being pressed downwards tends to cause the lower end to be tilted backwards. This is resisted by the strong sacro-sciatic ligaments, and as a result a sharp bending forwards of the lower end is frequently brought about.

The iliac bones, which, in the young child suffering

from rickets, may be thickened and swollen during the active stage of the disease, are frequently, in the adult, more delicately shaped than normal. The sinking of the promontory of the sacrum is strongly resisted by the strong ilio-sacral ligaments, resulting in a pull which tends to draw together the posterior superior spines of the ilium. As a result, the posterior part of the iliac fossa is often rendered more abruptly concave by a curling inwards and forwards of its posterior margin, while the anterior portion of the crests and the iliac fossæ tend to spread outwards, so that the anterior superior iliac spines are further apart. The softened iliac bones are further flattened by the weight of the viscera. The pelvic arch is usually wider than normal, and the tuber ischii may be everted, so that the transverse diameter of the outlet may actually be exaggerated. When the lower end of the sacrum tilts backwards, the antero-posterior diameter of the pelvic outlet is also increased. Thus, while the pelvic inlet is contracted, the pelvic outlet is wide and gaping.

This action on the pelvis is important, for it means that the conjugata vera is always shortened, and the brim of the pelvis becomes oval, reniform, or heart-shaped. The transverse diameter is not usually much affected, but it may appear relatively enlarged and is sometimes absolutely so. This is the ordinary form of simple flat rickety pelvis.

Another form is the generally narrowed flat rickety pelvis, which corresponds to the variety already described, except that all the diameters are shortened instead of the conjugate only.

The pseudo-osteomalacic pelvis is usually due to a very severe form of rickets and is associated with grave forms and degrees of contraction. The walls of the pelvis collapse so that the sacrum and the lateral walls approach one another, giving rise to a small trefoil brim. Happily, such a condition is not now common.

The scolio-rachitic pelvis is a commoner and therefore more important variety, and is met with, as the name implies, in cases where the deformity is associated with lateral cur-

vature of the spine. Lateral curvature in the lumbar portion of the spine may by itself produce a certain amount of asymmetry of the pelvis, one side being somewhat more roomy than the other. Only slight degrees of contraction can, however, be produced in this way. When, however, as is usually the case, the scoliosis is associated with rickets, it may produce an extreme degree of oblique deformity associated with flattening. In these cases the inlet at the brim is smaller on that side to which the convexity of the lumbar scoliosis points, and the sacrum is pushed over to that side. Owing to increased pressure on one wing of the sacrum, the bone tends to be less well developed, and this may also affect the iliac portion of the sacro-iliac joint.

The pelvis is tilted so that the more contracted side is higher than the other, and the ischial tuberosity on this side is also higher, while the pelvic arch points to the contracted side. The conjugata vera runs obliquely backwards, the transverse diameter is always shortened, and the oblique diameters are unequal.

Towards the end of pregnancy, the existence of flat pelvis may be suspected from the fact that the presenting part cannot engage in the brim and therefore remains freely movable, so that the child lies high and well forwards, producing the condition known as pendulous belly.

Mechanism of labour in simple flat rickety pelvis.

During labour, the head is pushed to the occipital side of the pelvis, so that the bitemporal diameter of the head engages in the diminished conjugate. The forehead now dips so that the anterior fontanelle becomes more easily palpable. The position of the head is transverse, and the anterior parietal bone, most commonly the right, tends to present so that the sagittal suture is nearer to the promontory of the sacrum than to the pubis. This is what is known as the Nægele obliquity. The head now passes the conjugate by the bitemporal diameter. In the commonest head presentation, the right parietal forms the presenting part and the left parietal bone rounds the promontory, frequently

receiving an indentation on its anterior part as it does so. This mechanism is exceedingly important in these cases of flat rachitic pelvises, for it is in cases of this nature that there is apt to be delay. To apply forceps in a case of flat pelvis, with the head at the brim, is to court danger. Gross hæmorrhages into the skull, as the result of the application of "high" forceps, are much more common than is generally supposed, and it is in such cases that this accident is likely

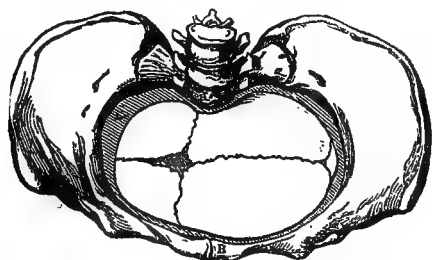


FIG. 5.—Flat pelvis showing compression of the head in the narrowest transverse diameter in a breech presentation.

to occur. The position of the head is transverse, and the grasp of the forceps is likely to be in the occipito-frontal diameter. Such a compression is dangerous to the child, and tends to lessen the size of the head in the roomy transverse diameter, and to make it bulge in the direction of the contracted conjugate.

In such a case, where the position of the anterior fontanelle is found to be low, the indication is for turning (see Fig. 5), which allows control of the labour and proper moulding of the aftercoming head.

CHAPTER XIV

Changes in the Bones of the Face in Rickets

THE changes which take place in the flat bones of the vault of the cranium have been described apart from those which occur in the bones of the base of the skull and the bones of the face.

Sir Arthur Keith conveniently divides the skull into two parts : (1) the flat bones of the vault of the cranium, which grow according to the requirements of the brain, the increase of growth taking place chiefly at the sutural borders, notably at those of the parietal bones. The anterior fontanelle forms, as it were, a focus or centre about which the most rapid growth takes place. In any errors these are the parts where defective growth is most apt to show itself, and in consonance with this, it is found that the chief changes in rickets, as has already been shown, take place along the interparietal or sagittal suture, and at the coronal and lambdoid sutures, and at the centres of ossification, especially those of the parietal bones, producing the characteristic parietal bossing ; (2) the base of the skull and the bones of the face, which are not concerned in the adaptation to the increasing size of the brain, but which have to do mainly with the act of mastication and the movements of the jaws, and with respiration. Even in wide deviations in growth of the bones of the cranial vault, the base of the skull remains remarkably constant and varies but little.

In rickets, the chief changes which occur in the bones of the face are found in the superior maxilla. There are two relationships of this bone which are of prime importance in the production of these deformities, viz., the association with the teeth and the function of mastication, and the

relationship to the nose and air passages and the function of respiration.

A quarter of a century ago, Prof. Marfan, of Paris, stated his belief that the co-existence of adenoids and rickets were the chief factors in the production of the high arched palate, which is the most characteristic deformation of the superior maxilla. Writing in 1907, M. Marfan says: "In 1896 I affirmed that the co-existence of adenoids and rickets is the most potent factor producing the deformations of the superior maxilla, and to-day I am able to affirm that rickets is the true cause of the high vaulted palatine arch."*

Keith, on the other hand, believes that this deformity of the palate is associated with a failure in the function of the jaws as a grinding machine, leading to defective growth of the bone, and he has recently pointed out some notable changes which he believes are taking place in the modern skull, using the term modern in the wider sense as dating from the Roman Period.† These are: (1) the high arched palate with irregularity and overcrowding of the teeth; (2) deepening of the orbit as if the lower external angle of the orbit were pulled downwards and outwards; (3) narrowing of the entrance of the nose by the laying down of an edge of bone along the lower margin of the nasal orifice; (4) thickening of the nasal bones, so that they are somewhat more prominent than normal. Keith ascribes these changes to errors of growth largely produced by modern habits, especially the change to soft and well-cooked foods which require but little mastication, in place of the rough and coarse grain foods on which man formerly lived.

Now there can be no question that profound changes have taken place in the modern skull within a remarkably short space of time—much shorter than is allowed by Keith—probably not more than between three and four centuries.

* "Le rachitisme dans ses rapports avec la déformation ogivale de la voûte palatine et l'hypertrophie chronique du tissu lymphoïde du pharynx." M. Marfan, *La Semaine Médicale*, 18th Sept., 1907.

† "Hunterian Lectures," Royal College of Surgeons, England, January, 1921.

Nor will the statement that the essential alterations in the bones of the face and skull are associated with a simple change of diet, interfering with the masticatory functions of the jaws, and so retarding and altering their growth, suffice as an explanation of these well-marked variations. These notable alterations in the bones of the skull, and of the upper and lower jaws, are due to a profound constitutional modification taking place in the growing infant, a change which is in once sense pathological, in that it is due to what is considered a diseased state, but which, in a very real sense, is purely physiological in that it is the natural response produced by the adaptation of the growing organism to a widespread and intense alteration in environment.

In other words, these changes are associated with the origin and spread of rickets which has taken place in England during the last three or four centuries.

For long after the Roman Period, right up to three and a half centuries ago, about the end of the sixteenth and the beginning of the seventeenth centuries, the same striking characteristics are met with in English skulls, viz., the wide roomy flat palate, and the beautiful regular arch of teeth meeting almost edge to edge, much ground down, but seldom decayed or missing. Nor did this form of jaw disappear suddenly. During the eighteenth century one gets a mixed variety, with a tendency to the modern contracted jaw, while others retain the more primitive form. But it is not till the rise of the great cotton industry, in the end of the eighteenth and the beginning of the nineteenth centuries, with the growth of huge industrial centres and great towns, that the jaws generally assume the type of to-day, where the teeth are markedly irregular and prone to decay, the upper set overlapping the lower, while the palate tends to be arched and high and the maxilla as a whole is stunted in growth. The superior maxilla is a membrane bone and its ossification begins early, about the seventh week of foetal life, and proceeds with great rapidity. The changes which occur in the bone as the result of modern environment arise at an early period, although it is not, as a rule,

till from the third to the sixth year, and especially towards the period of the second dentition, that the characteristic signs of alteration appear and the deformation of the jaw is found to be already accomplished.

Now, while the partial loss of the grinding function of the jaws may have some effect on the growth of the bones of the face, the main cause of the changes in the modern skull lies much deeper. The high arched palate is more common in the town than in the country, and it is more frequent among the poor than among the well-to-do. It is especially common and most severe in the slum dwellers and those from the lowest grade of society. If well cooked, easily masticated food were the chief cause it might be expected that the condition would be more prevalent among the rich. It is quite otherwise. The association of the arched palate with crowded and defective teeth, though by no means uncommon in the upper classes, is much more frequent among the slum dwellers.

Again, it must be noted that the change is a very early one. During the first two years of the child's life the grinding action of the jaws, even among native races, is brought but little into play, and by this time the changes in the superior maxilla and teeth have already made considerable progress. A grave objection to the theory that the changes in the jaws and teeth are dependent on loss of the function of mastication will be noted in the following chapter. By the end of the second year most of the gross defects of development of the *permanent* teeth, which are commonly associated with rickets, are fully developed, although the first permanent molar does not erupt till the sixth year. That is, the deviation from the normal occurs while the germ of the tooth is still deep in the jaw, long before there is any possibility of the function of mastication having any action. Already, in the second year, the growth of the permanent teeth is stunted, and the gross enamel changes, which are exposed when the teeth are erupted, are fully developed. The formation of the permanent teeth is an important factor in the normal growth of the jaws, and the fact that at

this early period gross defects are already present in the permanent teeth has an important influence on the development of both maxillæ. Softening of the bone of the superior maxilla, which occurs in rickets, is largely responsible for the persistence of the arching of the palate, and the approximation of the alveolar margins, which are so commonly associated with the presence of adenoids and with mouth breathing.

The great thickening of the membrane bones of the vault of the cranium, which tends to occur in rickets, has already been dealt with, and it has been noted that this thickening is often very persistent and may remain to late adult life. The superior maxilla, to a much less marked degree, also shows a tendency to thickening, but this is much less marked than in the cranial bones.

In the adult, variation in the thickness of the walls of the antrum of Highmore, is one of the reasons why transillumination of the antrum cannot, by itself, be considered a reliable sign as to the presence or absence of pus in that cavity. In a fair proportion of cases, where the crescentic illumination below the orbit is missing, and the shadow generally appears darker than normal, suggesting the presence of pus, puncture and washing out of the antrum reveal the fact that it is quite clear. This failure of the illumination may be due to several causes. Deflection of the septum of the nose may interfere with the illumination, as also may gross enlargement of the turbinate bones, but a fairly common cause is a general thickening of the maxillary walls. When present, this is usually rachitic in origin and may persist into late adult life. As a rule, however, the walls of the antrum are thin, and there is much less tendency to thickening of the maxillary walls in rickets than there is in the case of the frontal and parietal bones. In this true rickets differs markedly from experimental rickets, and from the so-called rachitic process which occurs in full grown animals in confinement. In these conditions enlargement of the bones of the face is very common, and is often well marked, while the thickening tends chiefly to

affect the superior maxilla. This is an exceedingly important distinction between true rickets and these artificially produced states.

The deformations of the jaws may be considered in relation to another function with which they are intimately concerned, that of respiration, a function which affects the growth of the bone at a much earlier age than that of mastication. Two air-ways may be used in filling the lungs, the one passing through the nose and the other through the mouth. A simple experiment will illustrate the effects of each. If the lips and teeth be lightly closed, and a long breath be taken in through the nostrils, the lungs can be fully inflated, especially in the region of the lower lobes of the lungs and posteriorly. This act is done with a conscious effort, and the muscles of inspiration can be felt raising and everting the ribs and expanding the base of the chest. If, now, the lower jaw be allowed to drop to its full extent and a deep breath be taken through the mouth, it will be found much less easy to satisfactorily fill the chest. The orifice and passage through which the air is taken in are much larger and the upper part of the chest is inflated, but the inspiratory muscles do not have the same point of vantage as when the mouth is closed, and while the act of shallow respiration is produced practically without effort with the mouth open, the full inflation of the lungs is rendered difficult.

In the healthy infant, when the environment is wholesome, the respiration is very active, as nature intended it should be, to cope with the rapid metabolism which is taking place in the child's system. But with the debilitated rickety child, living in a slum dwelling, healthy interchange between the blood and fresh air is impossible, and nature adapts the child to the altered environment by limiting the demands for fresh and pure air which is not obtainable. The muscles are thrown out of action and in every way nature minimises effort. As far as is compatible with growth, the metabolism of the body is conserved and the flabby, soft, dull-complexioned, apparently complacent and precocious child

results. It sits quite still and does not learn to walk or to speak till a comparatively late period ; it seldom cries. The breathing is shallow and the air is inspired without effort by the mouth, the apices and the bases and the anterior and posterior borders of the lungs being but little used. But such a child is adapted to its surroundings, and for the safety of the race the adaptation is necessary, where large masses of the population are herded together in surroundings wholly unfit for the rearing of infant life, or at least for the production of healthy growth and development.

In these first few months of the child's life are sown, not only many of the seeds of future diseases, such as decayed and defective teeth, otitis media and deafness and nervous diseases, but the whole physical and mental growth is aborted, or at all events does not reach the level of attainment which might otherwise be reasonably expected.

Among the Flemish painters of the fifteenth century, as will be shown later in discussing the history of the disease, the "front olympien" of an undoubted rickety variety had come to be associated in the popular mind with ideas of dignity and beauty ; similarly to-day, a type with short upper lip, and slightly prominent upper teeth, and *nez retroussé*, has been evolved and is held to be a somewhat distinguished variation. Yet these individuals have suffered from adenoids and from a mild form of rickets. Nor are they by any means confined to the lower grades of society. Such a type has probably suffered from a slighter and more evanescent form of the disease than has the heavy featured, sallow-complexioned and badly developed individuals characteristic of the slums. There is a male type of growth and a female type, and they may show a varying response to the same factor. Sir Arthur Keith has pointed out that the changes which occur in the cranium, and especially in the bones of the face, as the result of modern conditions, are much more common and more marked in the female than in the male.

In rickets, the lower jaw frequently tends to drop through muscular debility, apart from any post-nasal

obstruction, and once developed the habit of mouth breathing is likely to persist. Though it may be controlled during the day it is likely to reappear at night during sleep. The breathing in the rachitic state is shallow and quick and is carried on with a minimum of effort. When adenoids develop at an early age, as they frequently do, they confirm the tendency to mouth breathing.

Now the internal pressure of the air in the interior of the nose is of great importance. It widens the nostril and depresses the floor of the nose, thereby flattening out the palate and keeping the alveolar arch well spread. The air pressure tells on the lateral walls and increases the space on either side of the septum. The constant passage of the current of air has a tonic effect on the mucosa and actually supports the lining of the nasal cavity. In the mouth breather the nostrils are narrow and the nose is thin and collapsed, and is obviously not used for breathing purposes. The mucous membrane over the turbinates is liable to become swollen and congested, and a negative pressure tends to be established in the region of the naso-pharynx, interfering with the proper ventilation of the ear through the Eustachian tube.* In health the lower jaw is maintained against the upper by muscular action, but as a result of the loss of muscle tone in rickets, the temporals, masseters, and the internal pterygoids do not act satisfactorily, and the jaw is allowed to drop.

Several factors thus contribute to the deformation of the superior maxillæ in rickets, viz. : (1) softening of the bone ; (2) the falling of the lower jaw, as the result of mouth-breathing, producing a continuous drag on the soft tissues of the cheeks, tending to approximate the alveolar borders of both maxillæ, and to perpetuate or increase the infantile arching of the palate. The constant and ever varying pressure of the tongue is an important factor, moulding the formation of the palate. With the dropped jaw of the mouth breather this pressure is rendered largely ineffective ; (3) the

* " Studies in the Anatomy and Surgery of the Nose and Ear," by Adam E. Smith, M.D. New York, 1918.

loss of the passage of the current of air through the nostrils, which normally tends to flatten the floor of the nose and to separate the lateral walls from the septum ; (4) the dwarfing of the permanent teeth, which leads to irregularity in their growth and eruption.

A further very characteristic and exceedingly common defect associated with rickets and with modern environment is deflection of the nasal septum. The septum of the nose is mainly composed of the vomer and the perpendicular plate of the ethmoid bone. It is fixed between the base of the skull above and the palatal plates of the superior maxillary and palate bones on its lower border, and it forms one of the supports of the bridge of the nose. This bony septum is prolonged forwards by the middle cartilage of the nose.

Deviations of the septum may take place in : (1) the cartilaginous portion of the septum ; (2) the bony portion when it may involve—(a) the vomer ; (b) the perpendicular plate of the ethmoid ; (c) more commonly both.

In considering the production of this deformity, it is to be noted that there is no give in the base of the skull. Normally, the palate of the infant has the shape of a Gothic arch, which becomes flattened as the air-way through the nose becomes developed and the naso-pharynx expands. Anything which interferes with the growth of the bones of the face, and especially with the descent of the hard palate, naturally hinders the growth of the vomer and of the perpendicular plate of the ethmoid. When the palate retains its infantile Gothic arch, and especially if this is increased, the bony and cartilaginous septum cannot expand, owing to the base of the skull being fixed, and a buckling of one or other or of both of these parts must occur. (See Plate V.) Deviations of the septum are frequently spoken of as if they were due to excessive growth of its bony and cartilaginous constituents. Such a conception is wrong. They are due to a failure of co-ordination in the development of the bones of the face, including among these bones, the vomer, and the perpendicular plate of the ethmoid, which really belong to the face rather than to the skull. This failure in the great

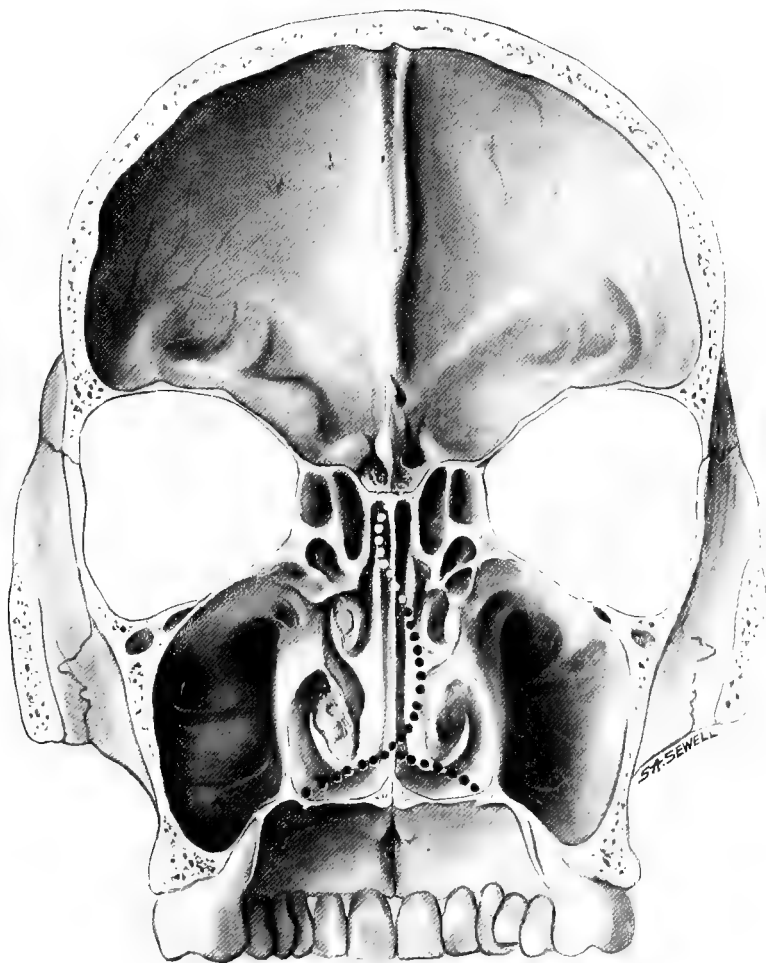


PLATE V.

Coronal section through the skull behind the first molar, showing the normal flattened condition of the palate. Dotted line indicates the vaulting of the arch of the palate which occurs in rickets, and the consequent buckling of the septum which takes place owing to the insufficient room for its proper expansion and growth.

majority of cases is rachitic in origin. In this way are produced the varying degrees of one type of deflected septum. Now all these changes depend on the fact that as a result of the rachitic process the bone is unduly soft and is easily moulded by outside forces. Indeed, if adenoids arise later on, apart from rickets, as the result of some infection, as they sometimes do, the adenoid facies does not develop.

As a result of my own experience in the examination of school children in London, when this was first undertaken by the London County Council, it was found that out of a large number of children of all ages about one in six suffered from enlarged tonsils or adenoids, or both, in a degree sufficiently severe to call for surgical interference. In a few years the effect of systematic treatment carried out on the younger children made an appreciable difference in the incidence of tonsils and adenoids among the upper school classes, and the percentage of cases requiring to be dealt with became, and has remained, very much smaller. Adenoid growths are not necessarily due to rickets, but the great majority of cases are undoubtedly associated with it, and indeed these growths usually form but a part of the general lymphatic hyperplasia which is commonly met with in this disease. Adenoids are the most common cause of mouth breathing, but it is important to remember that before the growths develop the debilitated child may acquire the habit. The infant and the young child have considerable difficulty in clearing the naso-pharynx and the upper respiratory passages from mucus. Young children do not expectorate, and it is only by the act of vomiting or through the action of the bowels that mucus can be removed. This is a matter of importance, for these rickety children suffer much from catarrhal conditions of the upper air passages, especially in winter, and without the presence of adenoids the naso-pharynx may be blocked.

In many cases the typical adenoid facies will develop in mouth breathers who do not actually suffer from adenoids, and in children who suffer from adenoids without rickets the characteristic facies will probably not appear.

Like many rachitic changes, deviations of the septum are exceedingly common among Europeans and are much less common among non-Europeans. As Tilley remarks, if a normal septum is one which is perfectly straight, and which divides the nasal cavity into two symmetrical halves, very few noses in Europeans would be free from defect.

In health, as already noted, the lower jaw is kept opposed to the upper jaw by muscular action, but in rickets, as a result of muscular debility, the temporals, masseters, and the internal pterygoids, do not act satisfactorily, and by their want of tone allow the jaw to drop. It will be noted that these are strong and powerful muscles, generally used in concert in keeping the lower jaw apposed. The opposite movement of depressing the jaw is largely a question of gravity and is therefore assisted by much smaller muscles, of which the digastric is the chief. In the relaxed condition of rickets the tendency is for the jaw to drop and the lower lip to be pendulous, hanging away from the jaw, and producing the vacant, stupid appearance often seen in these debilitated children. This tendency is accentuated when there is post-nasal obstruction, especially that associated with adenoids.

Marfan, following Fleischmann, describes the lower jaw as being flattened in front between the canines, while the horizontal rami are approximated, and tend to join the flattened front portion of the jaw almost at a right angle. The lower border of the body of the jaw is described as being in advance of the superior border, which is stated to be directed inwards, producing the "*menton de galoche*," or long pointed chin. Such a jaw is not typical of rickets. It suggests an overgrowth rather than a failure of growth, which is characteristic of the rachitic lower jaw, such a condition, for instance, as is found in acromegaly when the strong massive jaw with a pointed chin is a conspicuous feature. The characteristic signs of rickets in the upper and lower jaw are not present in all cases, and are most marked when the child is a continuous mouth breather.

Normally, the vertical ramus of the lower jaw mounts

up from the posterior border of the body or horizontal ramus of the jaw at nearly a right angle in adult age. Into this vertical portion of the bone are inserted the powerful muscles which close the jaw. In rickets the lower jaw, hanging continually during growth, does not develop properly, nor do the muscles attached to it attain their proper size and strength. The whole mandible is small and the chin is receding. The angle of the jaw tends to become notably obtuse instead of approaching a right angle. The horizontal rami of the two sides are approximated by the pull of the soft tissues of the side of the face and neck. In the normal skull the bite of the incisors is scissors-like, the lower incisors biting just inside the upper teeth. This adapts them the better for their nipping-off action and prevents the tendency to trauma which would be present if the sharp edges were accurately opposed. The labial surface of the lower canine strikes against the lingual surface of the upper eye tooth. The biting surfaces of the molars and premolars are not in the same horizontal plane, that of the lower teeth forming a slight curve with the concavity upwards, which receives the morsal surfaces of the premolars and molars of the upper jaw which form a slight convexity. In addition, the grinding teeth are so arranged that, when the jaws are closed, the tooth in one jaw is opposed by two in the other. In this way the teeth are excellently adapted for the biting action of the incisors and the piercing and holding action of the canines, and yet allow apposition without interfering with the grinding action of the molars.

In the rachitic skull the scissors-like action of the incisor teeth is greatly exaggerated, and indeed, in the modern skull in Europe generally, the upper incisors markedly overlap the lower. At the same time the teeth are irregular, due to overcrowding, and the upper central incisors tend to be prominent, and are often only partially covered by a short upper lip, while the canines and lateral incisors of both jaws are apt to be misplaced.

There can be but little doubt that this condition is pathological, and is part of the penalty paid for the unnatural

overcrowding of modern populations, into great industrial centres and huge cities. In the male, though a weak lower jaw is a common rachitic deformation, it is less common than in the female. Not infrequently the mandible of the male is relatively well developed and is but little affected. A fairly common variation is met with where the palatal arch and the alveoli of the upper jaw are contracted and badly developed, leading to overcrowding of the teeth, while the lower jaw is strong and practically unaffected. Seen from the front, it looks as if the thumb and forefinger had been placed on the upper lip, one on each side of the nose, and the face had been forced backwards, producing flattening in this area. The result is that instead of the upper teeth overlapping the lower teeth, as is most common in the modern jaw, they may meet, or the lower teeth may project beyond the upper, producing a form of false prognathism.

The tendency to irregular arrangement and early decay of the teeth, and to deformations of the jaws, are evils associated with a vicious environment and are not due to any inherent or unavoidable degeneration taking place in these structures. If the changes in the jaw and teeth were due to loss of function, owing to the diminished action required in the mastication of modern food, the position would be somewhat hopeless, for there is not much likelihood of modern people returning to a primitive dietary. The grinding down of the incisors and canines, as well as of the grinding teeth proper, frequently almost to the sockets, which is so common in skulls up to the sixteenth and seventeenth centuries, shows that these early people used food, not from choice but from necessity, for which their teeth were wholly unadapted by nature. In all probability this was a potent factor shortening the duration of life. It is usually somewhat lightly inferred that the use of harsh foods and coarse grains in primitive times made for healthy growth and development, while the truth is, that it was neither wholesome, nor well adapted to the economy of the individual.

With wholesome food to-day there is ample work for the

proper development of the jaws and teeth. The eating of raw apples and other fruits, as is done by the children of the poor from an early date, should be encouraged. It has an excellent double effect in cleansing the teeth and in giving the necessary exercise to the masticatory muscles, which are otherwise not much used. But such a diet is easily carried to excess, and it is not desirable to feed the young child on raw vegetable salads, for which its digestion is not adapted, and from which the growing organism finds difficulty in withdrawing the pabulum required for its rapid metabolism. The digestion of the young child is very tolerant, and even in the rachitic child is but little affected, but if meat be excluded from the dietary and large quantities of vegetable foods containing much cellulose be substituted, the best results will not be obtained either as regards, physical or mental development. A generous diet, which is varied and includes everything that is wholesome, is best adapted for growth.

In discussing the changes occurring in the flat bones of the vault of the cranium, it was shown that the tendency was to produce a brachycephalic type of skull. The changes in the bones of the face tend to produce elongation of the face and the lantern-jawed type of individual.

CHAPTER XV

The Teeth in Rickets

IN many diseases there is a marked tendency for morbid processes to exert a selective influence and to attack certain tissues of the body. This is very notable in syphilis, and Jonathan Hutchinson long ago pointed out the remarkable tendency in certain cases for one set of tissues only to suffer.* Thus, in syphilis the skin surface may be the seat of multiple lesions to the exclusion of other structures. At other times it is the mucous surfaces which suffer; not infrequently it is the periosteal tissues or the central nervous system which is alone or mainly affected. In no disease is this tendency more marked than in rickets. Tissues which are related to each other developmentally are frequently subject to like degenerations. In rickets there are four tissues, widely separated, which are often markedly affected, viz., the teeth, the lens of the eye, the skin, and the central nervous system. These various and dissimilar structures are at once linked up when it is remembered that they are all ectodermic in origin, and that they are all developed from the outer germinal layer. In the teeth, the eye, and the skin, these changes are easily demonstrated to the naked eye and by the microscope. In the nervous system, the state of present day knowledge of the intimate structure of the neuron does not yet allow accurate dogmatic statements in regard to histological changes in diseased conditions; but the profound and constant series of nervous symptoms which supervene in rickets, warrant the inference that there is probably an actual physical basis for these symptoms in alteration of the nerve cells themselves. Our knowledge of

* "Syphilis," by Jonathan Hutchinson, F.R.S., LL.D., Lond., 1889. Commentary CLX, p. 330.

the pathology of the nervous system, even in epilepsy, which has been studied from the most ancient times, is no further advanced than it was in the days of Hippocrates. One thing seems clear, that heredity is not the all important factor in its production. The causes of epilepsy are various, but they act on a prepared soil not necessarily inherited ; as will be shown, there is reason to believe that the pathological condition of the nervous system which leads to the development of epilepsy is probably, in very many cases, acquired in early infancy, and is frequently associated with the rachitic state. Certainly there can be no hesitation in connecting up the convulsions of infancy with epilepsy, and the identity of the two conditions in many of these cases is now established. If these observations are accurate they are capable of a very wide and important application.

The changes in these various structures will be studied in sequence.

Defect in the calcium metabolism, especially in the laying down of calcium salts throughout the skeleton, is the most prominent feature in rickets, and is the one responsible for most of the physical signs which mark the disease. Nowhere is this factor more marked than in the teeth. In rickets caries is exceedingly common, and hypoplasia, or defective calcification of the enamel, is well marked. This defective laying down of the enamel is not necessarily the result of rickets. It may be the result of many general disorders, and is occasionally seen in an isolated tooth as the result of some local irritation, the defect in the enamel being confined to that area of the tooth which was undergoing calcification at the time of the general or local disorder.

A hypoplastic condition of the teeth * is characterised not only by a defective formation of the enamel, but also frequently by a stunted growth of the teeth. There may be only a pitting, producing a honeycombed appearance of the enamel, or the enamel covering is slight, and the cutting

* "The Teeth in Rickets," by J. Lawson Dick. "Proceedings of the Royal Society of Medicine," 1916, Vol. IX (Section for the Study of Disease in Children), pp. 83-89.

edge of the tooth presents sharp points, giving a characteristic appearance to the tooth. The defect usually extends from the cutting edge, and may, in severe cases, involve the whole crown. As in syphilis, the condition is found typically in the permanent dentition, but whereas the notched incisors and the contracted first molars of syphilis are but rarely met with in school children, the hypoplastic teeth of rickets are common. In every-day life one constantly sees these teeth and notes how well they often last. Thus, frequently a smoker is seen whose teeth have been worn down in depth, and only short stumpy teeth are left, with a layer of enamel all around the cutting edge and the dentine exposed in the centre of the biting edge.

Robert Bunon, an illustrious French dentist of the earlier part of the eighteenth century, first accurately described this condition. Bunon's work is of a very brilliant and original nature, and in so far as it is the result of actual and acute observation, it remains as accurate to-day as when it was first written, and much of it has been rediscovered without being amplified. It is interesting to note that Bunon practised in the north of France, Antwerp, Brussels and elsewhere, all localities where he would be likely to come into contact with rachitic states. In contrast with the frequent diseases of the teeth in these parts, he refers to the common belief of the time that the peasant Savoyards have very regular white teeth, free from disease. In 1743, Bunon published his remarkable work on the teeth* Rickets, Bunon shows, is one of the chief causes of many defects of the teeth, such as lateness in eruption of the primary teeth, and of malformation and irregularity, early decay, overcrowding, the result of malformation of the jaws in the second dentition, and well marked hypoplasia, of which he gives a very accurate and full description. Erosion, as this hypoplastic defect was termed by Bunon, sometimes affects the milk teeth, but is much more frequent in the

* " *Essay sur Les Maladies de Dents, l'on propose les moyens de leur procurer une bonne conformation dès la plus tendre Enfance, et d'en assurer la conservation pendant tout le cours de la vie.*" Par M. Bunon, Chirurgien-Dentiste, à Paris, 1743.

permanent teeth. Those most often affected, he observes, are the first molars, and in frequency follow the incisors, canines, premolars; the second and third molars are most rarely affected.

Besides rickets, measles, small-pox, malignant fevers, and notably scurvy, all produce hypoplasia of the teeth, the area of the teeth affected in all these conditions depending on the part of the tooth which was being calcified during the period of the disease. A still greater observer followed Bunon. John Hunter was at work on the teeth about the middle of the eighteenth century, and published his work in 1771.* Hunter deals with hypoplasia under the heading of "Decay by Denudation." It is hardly likely that he was acquainted with Bunon's work, for if he had been cognisant of it, it would have cleared up many points on which he was somewhat vague. That Hunter was well acquainted with the condition is apparent from the number of specimens he collected. One such excellent specimen is figured in Plate VI.

Besides the well marked examples in the Royal College of Surgeons, London, there are several in the Hunterian collection of Wm. Hunter, in the University of Glasgow, which were almost certainly prepared by John Hunter while assisting his brother. It is another example of the wide range and the unvarying patience of Hunter's methods of investigation. These teeth were laboriously prepared by him and were set on one side, left, as it were, till further observations would help him to complete the scheme. Sir Frank Colyer † believes that in the chapter on "Decay by Denudation" Hunter was referring to the state of the teeth produced by abrasion, that is, the wearing away produced by friction from tooth brushes, powders, etc., and that he did not recognise the process as such. There can be little doubt that Hunter was referring to true hypoplasia and not to the effects of abrasion, though he ascribes it to a form of

* "The Natural History of the Human Tooth, Structure, Use, Formation, Growth and Diseases," illustrated with copper plates, to which is added a "Practical Treatise on the Diseases of the Teeth," by John Hunter. Third Edition, London, 1803.

† "John Hunter and Odontology" by J. F. Colyer, London, 1913.

decay of the enamel whereby more and more of the bone becomes exposed, due to a denuding process. "I have seen instances," says John Hunter, "when it appeared as if the outer surface of the bony part, which is in contact with the inner surface of the enamel, had first been lost, so that the attraction of cohesion between the two had been destroyed, and as if the enamel had been separated for want of support, for it terminated all at once." In certain instances this process of denudation does occur, and may be seen in the imperfectly formed enamel on the crown of the first molar. I have myself seen the process of denudation taking place, on more than one occasion, on the flat surface of the crown of the first permanent molar. It seemed as if the defect in the enamel chiefly affected the layer in contact with the dentine. As a result of slight trauma the enamel fractured and peeled off in large flakes, leaving the exposed dentine below. Occasionally I have been able to raise large flakes of enamel with the wooden spatula, exposing the dentine already blackened, consolidated, and insensitive, the process of decay having become arrested.* But the ordinary form of hypoplasia consists, not in a denuding process, but in a defective laying down of the enamel, or, it may be, its complete absence, leaving the dentine below either imperfectly covered or entirely without covering. "From its attacking certain teeth," says Hunter, "rather than others in the same head, and a particular part of the tooth, I suspect it to be an original disease of the tooth itself; and not to depend on accident, way of life, constitution, or any particular management of the teeth."

The observation is accurate in so far as hypoplasia is an arrest or a perversion of the development of the tooth itself, due to some morbid condition affecting the system at the period that calcium is being actively laid down in the enamel. That John Hunter was not dealing with the state of the teeth produced by abrasion, but with a condition of true hypoplasia, is quite clear from a study of Plate VI.

* "Defective Housing and the Growth of Children," by J. Lawson Dick, London, 1919, pp. 45, 46.

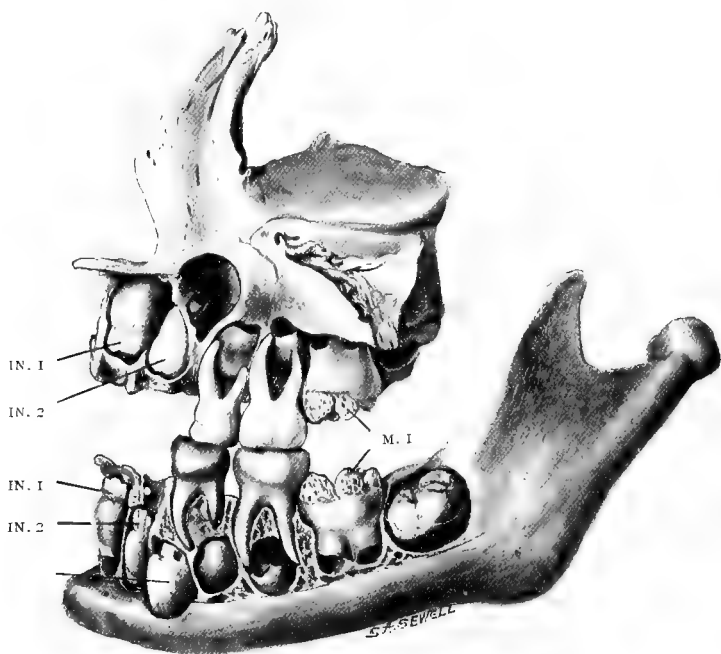


PLATE VI.

Left maxilla and left mandible of a child, age six years. The first permanent molars are erupted. The other teeth of the second dentition have been exposed by removal of the outer bony wall of the crypts. Typical hypoplasia of the rachitic type is seen in the two incisors of the lower jaw, and in the central incisor of the upper jaw, in the tip of the lower canine (upper canine missing), and in the crowns of the first molars. It is quite evident from this and other specimens prepared by John Hunter that he was well aware that the defect in the teeth arose as an original fault in the calcification of the enamel; in this specimen the incisors and canines have never been exposed to any form of attrition.

In this specimen, prepared by John Hunter himself, the first molar is the only tooth of the permanent set which has been erupted, and to expose the incisors, canines and premolars the outer wall of the jaw has been removed. Obviously, none of these teeth had been exposed to any form of attrition. It is also quite evident that the hypoplasia present is a defect in the actual laying down of the enamel. This specimen, though it was not recognised as such by John Hunter, is a typical example of hypoplasia due to rickets. From the extent of the enamel affected it can be stated fairly definitely that the child suffered from rickets during the first year or eighteen months. After the eighteenth month the calcification of the enamel proceeded normally.

Another point of interest is that the second upper permanent incisor becomes calcified later than the central incisor, and indeed, not infrequently escapes, as in this specimen. Even when it does not escape the defect is deeper in the upper central incisor than in the lateral. The lower incisors, canines and first molars are always affected when the upper teeth are imperfect. In the lower teeth the process is usually not quite so extensive as in the upper teeth, but the lateral incisor hardly ever escapes as the upper lateral incisor does. Usually the lower central and lateral incisors are fairly equally affected, as in John Hunter's specimen.

One century later another master mind was at work on the same subject. In 1858, Jonathan Hutchinson first published his observations on malformed teeth,* and this work continued to occupy his attention for many years. Hutchinson resembled John Hunter in many ways. He was a great observer, who took the whole of medicine within his purview, and such were the qualities of his mind that he could approach most branches with a special knowledge, such as could only be acquired by most individuals after a life-long devotion to that one study. He was an indefatigable collector, and, like Hunter, laid aside much material which he could not at the time explain, often throwing out tentative suggestions as possible explanations,

* "Syphilis," by Jonathan Hutchinson. Commentary CCXII.

but never failing to seize every opportunity of adding to his knowledge, and a long life fortunately enabled him to bring much of his work to maturity. Hutchinson established the fact that a crescentic or semilunar defect in the laying down of the calcium in the two upper permanent central incisors was pathognomonic of inherited syphilis. Although he agreed with the observations of Mr. Moon and others that certain peculiarities in the other teeth, notably in the first permanent molars, the dome-shaped teeth, were suggestive of an inherited syphilitic taint, he always maintained that the central upper incisors of the second set were the test teeth. Hutchinson recognised clearly that there were many varieties of hypoplasia. In the diagnosis of syphilis, he correctly states, all transverse markings across several teeth on the same level are to be disregarded, as also are defects which lead to pits or honeycombing. Foliated or wart-like projections on the teeth, with defective enamel and peg-like teeth were, he taught, suspicious but untrustworthy signs of syphilis. Hutchinson believed that all cases showing the characteristic semilunar defect in the edge of the upper central incisors were due to inherited syphilis, but he was never able to give any satisfactory explanation of the far more numerous forms of hypoplasia other than this which he met with. The only explanation he could bring forward was that these defects were due to the use of mercury in early infancy. "I regard it as certain," he says, "that mercury employed in infancy is attended by much danger to the development of the child's permanent teeth." This was for long a common belief. "'Tis fit," says Sir John Hill, in his herbal, in 1771, "that the world should be reminded that half the defective teeth in our young people are owing to mercurials given to children." This was a natural confusion when it is considered that it was customary to push the use of mercury in syphilis till salivation had been produced. The loosening of the teeth, as the result of ulcerative stomatitis, naturally led to the supposition that nearly all defects of the teeth had their origin in the administration of this drug.

While any agent which produces severe and prolonged stomatitis might reasonably be supposed to produce occasional hypoplasia, it is practically certain that mercurial stomatitis in early infancy is one of the rarest causes of this condition. Hutchinson's teeth are comparatively rare, while the other forms of hypoplasia are exceedingly common, and probably affect some seven or eight per cent. of the whole population. It is impossible to account for a condition of such frequent occurrence by prolonged mercurial stomatitis in infancy.

The term hypoplasia was first used by Dr. J. E. Grevers, of Amsterdam,* who emphasised the fact that all these defects tend to follow the incremental lines of growth in the enamel. Normal enamel consists of two portions: (1) the rods, which are a product of the ameloblast cell, are built up of little blocks of coalesced granules, and are arranged like piles of bricks; they show a cross-marking where they meet one another, which is the cause of the minute cross-striations of the enamel prisms; (2) the cement substance between the rods which, according to Leon Williams,† is calcified independently of the rods, cementing them together and forming a compact tissue, which in normal enamel is completely calcified and contains no trace of organic matter. Enamel in human teeth, according to Mummery, is seldom if ever a perfect tissue. Imperfections, especially at the dentine margin, and minute channels from the dentine are so common as scarcely to be looked upon as abnormalities.‡

The organic matter, in which the lime salts are either mechanically deposited or are secreted, as it were, by a vital process of the ameloblasts, loses its original structure and tends to become clear, uniform and structureless, constituting the densest and hardest of animal tissues. According to

* "Hypoplastic Teeth." "Transactions Odont. Soc. of Gt. Britain," Vol. XXVII, 1895.

† "A Contribution to the Study of Pathology of Enamel," by J. Leon Williams. "Dental Cosmos," Vol. XXXIX, 1897.

‡ "The Microscopic Anatomy of the Teeth," by J. Howard Mummery, London, 1919.

Colyer,* the commonest malformation is a failure of the cementing substance between the enamel rods in the outer one-fourth to one-third of the surface of the enamel, and frequently a colouring matter is formed in place of the cementing substance. Two theories may be stated as to the origin of caries: (1) that it is due in its inception to the solvent action of acids which have been generated by fermentation in the mouth, due to the action of micro-organisms; (2) that it is due to the vulnerability of the enamel, owing to defects in its minute structure rendering the teeth more readily liable to the action of organisms, and also to injury, which still further exposes the deeper layers to their activity. As already noted, fracture of the enamel in the case of the first molar is quite common. It seems reasonable to suppose that the best defence of the teeth lies in the laying down of perfect enamel, and the probability is that micro-organisms do not materially interfere with the teeth provided that the tooth is of healthy normal structure. It is well to inculcate cleanliness of the mouth, especially in communities where the teeth are liable to premature decay, but no amount of attention to oral hygiene will be entirely effective when the first and best defence of the tooth has been imperfectly laid down, as occurs in the slum populations of our large industrial cities. The occurrence of rickets in early infancy is the most potent factor in the production of defective teeth.

The calcification of the teeth begins about the fifth month of intra-uterine life, and the following diagrams give the rate of progress of calcification at various periods for both the temporary and permanent teeth.

The only teeth of the permanent set which show any signs of calcification at birth are the cusps of the first molars. Fig. 8, p. 199, shows the portion of the enamel which has undergone calcification at the end of the first two years of life, and the parts affected by the commonest form of hypoplasia.

* "Dental Surgery and Pathology," by J. F. Colyer, F.R.C.S., L.D.S., London, 1919.

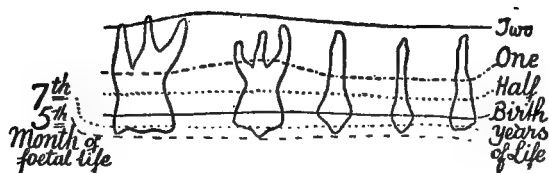


FIG. 6.—Showing calcification of temporary teeth at various periods.

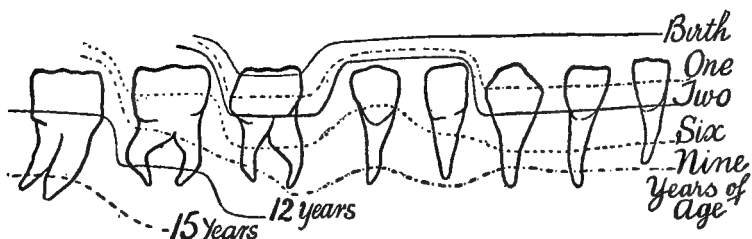


FIG. 7.—Showing calcification of permanent teeth at various periods.

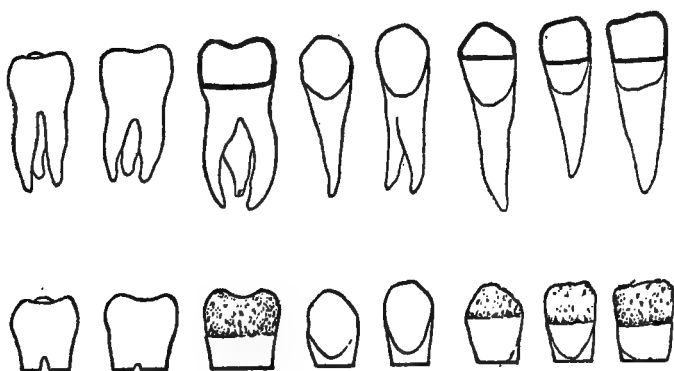


FIG. 8.—Permanent teeth, showing the parts calcified in the first two years.
Below to show the parts affected by commonest form of hypoplasia.

In the typical form of hypoplasia commonly met with, the teeth affected are the central and lateral incisors, the tips of the canines, and the crown of the first molars. The condition is symmetrical, affecting both jaws. The biting edges of the incisors are almost always affected, and the deficiency of enamel extends for some distance on the labial and buccal surfaces of the teeth towards the gum. As a rule, only the very tips of the canines, and the biting surfaces, with one quarter to one third of the crowns of the first molars are affected. These teeth will again be referred to in some detail in speaking of the association of rickets with lamellar cataract. Usually the depth of the defect is greater in the enamel of the central incisors than in that of the lateral incisors, and it will be noted that the enamel affected is identical with that laid down during the first two years. This condition is pathognomonic of rickets. Rickets is the only condition which interferes with the deposition of calcium over this prolonged period. As already noted, the upper lateral incisors are occasionally passed over. The dentine is either thinly coated with badly laid down enamel, which tends to be brown and discoloured by the collection of sordes in the irregularities, or the dentine may be entirely exposed and irregular, and jagged dentine, which rapidly becomes blackened and consolidated, is exposed at the biting edge of these teeth. This tends to become worn down in adult life, so that the condition may be completely masked, owing to the fact that the exposed dentine has been completely ground away (see Plate VII, Fig. 1).

In cases of acute illness, especially fevers, the finger nails are apt to show grooves marking the state of depressed growth of the cells of the bed of the nail during the progress of the disease. In the case of the teeth, a groove more or less broad, or even a succession of grooves with healthy enamel in between, may mark attacks of grave illness in the child. Frequently, without a history, a shrewd guess can be made at the period of occurrence of some serious illness by the part of the enamel of the teeth which is affected. But it is usually a grave and prolonged illness which thus leaves

PLATE VII.

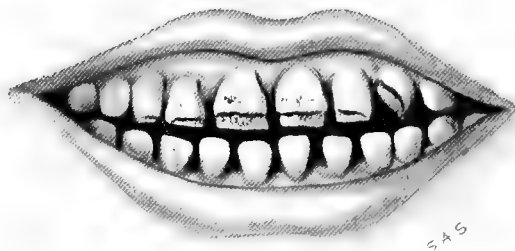


FIG. 1.

Appearance of the teeth in a discharged soldier of 21 years of age suffering from double lamellar cataract. The teeth are small and stunted. The upper central incisors, the lateral incisors and the canines all show typical hypoplasia, although the exposed dentine has been a good deal ground down in the upper jaw. The lower jaw has also exhibited hypoplasia, but the exposed dentine has been entirely ground down.



FIG. 2.

Hypoplasia in the form of a deep groove running across the central and lateral incisors and the canine. This form of hypoplasia is not usually due to rickets but is characteristic of the condition produced by a severe and prolonged debilitating illness such as measles, especially when accompanied by whooping cough. From the part of the teeth affected it can be definitely stated that the disease producing this condition occurred about the age of eighteen months.

its mark, more especially measles, followed by whooping cough. Scarlet fever is less likely to have this effect.

This form of hypoplasia (see Plate VII, Fig. 2) is not typical of rickets, but is more commonly due to an attack of some severe or depressing illness. In my experience, the commonest of the children's diseases to give rise to this groove is measles, more especially when this is accompanied by whooping cough. Both upper and lower teeth of the permanent set are affected in a similar way. From the part of the enamel affected in Plate VII, Fig. 2, it can be fairly definitely stated that the illness occurred at the age of from eighteen months to two years.

At birth calcification has involved the crowns of the deciduous incisors, the cusps of the deciduous canines and deciduous molars, and the tips of the cusps of the first permanent molars. The portions of the enamel not yet calcified at birth in the temporary set frequently suffer from hypoplasia. While a considerable portion of the crown of the tooth is already laid down in the new-born infant, the enamel round the necks of the teeth have not yet been formed. It is suggestive, that in the decay which is so common in the temporary set in rachitic children, that the necks of the teeth frequently show advanced caries, indicating that there has been some failure in the defence of the enamel at this part.

Any disturbance in the function of the ameloblasts, the cells which, according to Tomes, either secrete the enamel or in which the calcium salts are deposited, will lead to the enamel being thin in parts and to the lime salts being imperfectly laid down, so that the compact enamel is more easily disintegrated. In other words, the agents which determine the tendency to decay are those which affect the soft enamel organ in the earliest history of the tooth, and not those which affect the enamel after the tooth has been erupted.

Seafaring communities are said to have good teeth, and this is generally attributed to the action of ozone and pure air. But more likely causes are the favourable conditions

under which the children of such communities are brought up in early life, as regards fresh air, sunlight and ventilation.

Sydney Spokes found that hypoplastic teeth were more commonly met with in the lower classes than among the well-to-do. He gives the following figures as the result of an examination of a number of public school boys and of Poor Law school children.

Class of School.	Percentage rate of incidence of hypoplasia.
Public School (258 boys)	4.6 per cent.
Poor Law School (1,463 boys and girls)	7 „

Some observations on the state of the teeth amongst rickety children in London County Council schools in the East end of London.

In judging of the presence of hypoplasia, it was found practically impossible to make accurate observations on the temporary teeth of infants of school age. Caries was so universal and extensive that it completely masked the hypoplasia. It was evident that a hypoplastic condition of the teeth was common in the temporary set, and was, in all probability, the chief factor in bringing about premature decay. For the purposes of statistics only the records of the permanent dentition have been taken, and in marking a case as one of hypoplasia only the severer forms are admitted, and cases of slight pitting, chalky-looking patches in the enamel, and so on, have been excluded, although microscopically such teeth would be found markedly defective and liable to disintegration. Of the 586 rickety cases in which a record of the permanent teeth could be taken, 42 per cent. had normal teeth, and 58 per cent had defective or decayed teeth; 20 per cent. of these showed hypoplasia frequently combined with decay, and 38 per cent. had decayed teeth. This is not equivalent to saying that 42 per cent of school children have normal teeth. As already pointed out, all infants with a record only of temporary teeth have been excluded, because these teeth were so universally decayed as to make accurate observations on the structure impossible. Again, most of the children with records of the permanent

teeth were about the ages of twelve or thirteen years, when all the permanent teeth have been erupted except the third molars, and caries has had least time to make its appearance. It is a somewhat quaint commentary on the general state of the teeth of the community to be compelled to explain why only 58 per cent. are given as having defective teeth.

Of the cases with carious teeth, the lower first molar was decayed in 80 per cent., the upper first molar was decayed in 30 per cent., one or more lower premolars in 30 per cent., and one or more upper premolars in 12·5 per cent. The incisors, canines and second molars were seldom decayed. The shape of the incisors and canines must protect them from many of the causes of decay to which the flattened grinding molars are subjected. The lower first molars decay out of all proportion to the others, and their earlier eruption is not a sufficient explanation of this. It is to be attributed rather to the main part of the enamel of the crown having been laid down in the first two years of life, when rickety conditions are operative. Naturally the lower teeth, which lie in the well of the mouth, will suffer more seriously from deleterious influences which surround the teeth.

Even though no macroscopic change indicative of hypoplasia is to be found in these teeth, in all probability their microscopic character is distinctly affected. One practical point may be noted. Frequently, on looking into a child's mouth, the two milk molars or the first permanent molar will be seen with blackened exposed dentine and the enamel on the surface of the crown removed. Closer examination will show that these are still effective teeth and that there is no pyorrhœa or gum irritation around them. The surface of the tooth can be freely touched with the spatula. The dentine of the tooth seems to have become consolidated, and usually, though the teeth do not look well, they can be safely left, the process of decay having become arrested.

Many of the conditions conducive to rickets are present in the parents of these children, and *a priori* it might be

expected that this would frequently be a congenital defect. In such a case, in a certain proportion of children, the milk incisors should show hypoplastic changes. The enamel of the crown of the milk incisors begins to be laid down about the seventeenth week, halfway through intra-uterine life, and has progressed to a considerable extent at the time of birth. At birth, half the crowns of the incisors, the tips of the canines and the cusps of the molars are calcified in the temporary set, and by about six months after birth the calcification of the crowns is completed. Careful search for a hypoplastic condition of the biting edge of the milk incisors during a long period, both in school children and in the babies who have attended infant welfare centres, has failed to detect a case. It is strong presumptive evidence that rickets is not a congenital condition, and is another instance of the care that nature takes, that whatever else suffers the germ at least is protected during intra-uterine life.

A later form of hypoplasia is every now and then seen, in which the two premolars and the second molars are affected, while the incisors, canines and first molars are not affected. This later form of hypoplasia must be due to influences acting on the child from the second to the sixth year.

If one hundred better-class children, living under good social conditions, are compared with one hundred poorly fed children, living under slum conditions, even a casual inspection will show that the teeth of the poorly fed and badly housed children are much more defective than those of the children living under better conditions.

Another inquiry was made as to the teeth conditions in 403 children taken from the ordinary London County Council schools.* All these children were eleven years of age and over, and of the 403 children, 281 were taken from schools where the general conditions as regards feeding and housing were distinctly below the average, whilst in 122 these conditions were relatively good. No attempt was made to select children of poor nutrition, beyond that they belonged

* "Abnormal Conditions of the Enamel in Cases of Malnutrition." *Lancet*, Oct. 5, 1918, p. 456.

to a poor school and lived under slum conditions in poor and overcrowded neighbourhoods, such as Bethnal Green and Shoreditch. As a contrast, 122 children were taken from good-class schools in North London, where the social conditions were fairly good, and where the general state of nutrition was good. The following results were obtained:—

(A) 403 children. (B) 281 where nutrition and environment were decidedly poor. (C) 122 children living under good social conditions.

		(A)		(B)		(C)	
		Cases.	Per cent.	Cases.	Per cent.	Cases.	Per cent.
Enamel normal	...	273	= 67·5	167	= 60	106	= 87
Enamel defective	...	130	= 32·5	114	= 40	16	= 13

Carious conditions have not been dealt with in these figures. The conditions of the enamel met with in these cases may be summarised as follows:—

1. *Typical rickety hypoplasia*.—This has already been dealt with.

2. *Honeycombed teeth*.—This condition is much the same as the first, except that the deficiency in the enamel leads to the formation of small depressed pits scattered over the surface of the teeth, giving a very characteristic appearance.

3. *Horizontal bands of thickened enamel and transverse grooves in the enamel*, indicating acute illnesses of a more or less prolonged nature. Short acute illnesses seem less likely to produce this condition than prolonged debilitating conditions, such as measles, especially when followed by whooping cough.

4. *Chalky appearance of the enamel*, varying from white patches or transverse bands on the surface of the enamel to a general opacity affecting its whole surface. This is a very well-marked defect, and the contrast which this condition gives with the clear semi-transparency of healthy enamel, is one of the chief things which strike the observer in the teeth of these badly housed and poorly nourished children.

5. *Brown lines of Retzius*, or brown staining of the

enamel, is a common and well-marked defect found in the poorer class of children. This defect may be found as a brown line, running as a rule across the incisors, and, it may be, the canines. It may be a brown patch of varying size and intensity of colouring, though it is usually a rusty brown. Very commonly it is associated with marked opacity of the enamel, and it seems to indicate a somewhat severe degree of disturbance of the nutrition.

Placing the frequency of occurrence in the poor-class and the better-class children side by side, the following is the result given in percentages :—

	In 281 poor-class children.	In 122 good-class children.
	Per cent.	Per cent.
Opaque chalky enamel	28.5	9
Brown line of Retzius	13.0	1 case
Hypoplasia	8.5	5
Honeycombed teeth... ..	2.5	9

As already shown, out of 281 poor children, 114, or 40 per cent., had defective enamel, as compared with 13 per cent. amongst the better-class children. Taking the 114 cases with defective enamel amongst the poorer-class children there was found :—

	Per cent.
Chalky enamel	80 = 70
Brown lines of Retzius	38 = 33
Typical hypoplasia	24 = 21
Honeycombed teeth	7 = 6

It is of great importance to note the teeth most commonly affected. In the children where the enamel was opaque and chalky the teeth were affected in the following order of frequency :—

	Per cent.		Per cent.
Central incisors	78	Premolars	20
Lateral incisors	55	First molars	10
Canines	30	Second molars	5

These figures are accurate, except in the case of the first and second molars. The first molars were frequently badly

decayed or the tooth had been extracted. The second molars in many of these cases had not yet been erupted.

In thirty-eight cases, where the teeth showed the brown lines of Retzius :—

				Per cent.
Central incisors affected in	...	...	36	= 95
Lateral incisors affected in	...	...	11	= 29
Canines affected in	...	...	5	= 13
First molar	...	...	1	case.

It is important to note that in hypoplasia, and in cases where the chalky patches and the brown lines of Retzius were found, the teeth which suffered chiefly were : first, the central incisors ; secondly, the lateral incisors ; and, thirdly, the canines, in this order of frequency. Reference to the diagram will show that the calcification of the enamel of the crowns of these teeth goes on during the first two years of the child's life. So that these defects are due to errors of metabolism affecting the child at this early period, when the rate of growth, and notably that of the brain, is relatively enormous.

CHAPTER XVI

Skin Affections in Rickets. Lamellar Cataract and some other Conditions of the Eye associated with the Rachitic State

Skin Affections in Rickets.

RICKETS is often brought forward as a common cause of eczema, on the ground that gastro-intestinal catarrh is erroneously held to be a constant factor associated with the disease. In so far as rickets is a constitutional condition, which depresses the health of the child and alters its metabolism at a very early period of its growth, it probably has an influence on the incidence of eczematous conditions, but these cannot be described as part of the disease or as being in any way directly due to it. Probably more than one-third and rather less than one-half of all cases of eczema in children begin within the first year of life, and, as is well known, they tend to be very persistent. Eczema at this tender age tends to assume the pustular form, and a certain intractable variety attacking the head, face, and neck, is very common. Often these children are very fat and appear in excellent health, and digest their food well without any tendency to sickness or diarrhoea. Naturally, excess of food suggests itself, bringing the condition into line with the gouty eczema of later adult life, but as a rule regulation of the diet has but little effect. The fact that it is most common during the time of eruption of the temporary teeth seems to suggest a connection with teething and irritation of the fifth nerve. Certainly many of these cases get well spontaneously, at the end of the second year after the milk teeth are erupted.

Infantile eczema, then, is most common during the period when rickets is most active and an indirect con-

nection between the constitutional condition and the skin manifestation is almost certain in many of these cases.

The possibility of a scorbutic factor in these inveterate forms of moist eczema about the head, face, and neck, should always be kept in mind. In scurvy there is a well-marked tendency to exudative conditions of the skin and mucous surfaces, and every now and then the condition yields readily to an anti-scorbutic. While it is tempting to believe that a constitutional cause or some source of reflex irritation is present in all these cases, and it is important to keep this possibility in mind, my own experience has been that they yield more readily to local treatment diligently applied.

In the young infant, one of the early signs of rickets, as has been seen, is a thin shiny appearance of the skin, especially over the forehead, so that the subcutaneous veins show through very markedly, and this is associated with greatly increased activity of the sweat glands of the forehead, neck, and shoulders, so that when the child sleeps the pillow is frequently quite damp where the impress of the head lies. Such a condition, however, is hardly an ailment of the skin, and is in all probability associated with defective oxygenation of the blood and the accumulation of an excess of carbonic acid, which is a marked feature of rickets. By the act of sweating itself much carbonic acid is removed from the system. As a result of the excessive sweating, miliaria or sudamina are exceedingly liable to develop, and may assume a vesicular form due to obstruction of the sweat ducts; or the eruption may be papular, as occurs in lichen strophulus or "red gum," where crops of red papules appear which cause much irritation and restlessness. Later, the skin of the rachitic child becomes coarse and the complexion pale and pasty.

But a very common and distinctive skin disease directly due to rickets is a form of xerodermia, or "dry skin." This condition is, I believe, characteristic of rickets, and is frequently found in well nourished children where there is no suspicion of scurvy and the supply of the anti-scorbutic

factor is adequate, but where rickets is markedly present. This is often classified as a congenital condition, but if careful enquiry is made, it is found that the infant was born with a healthy skin which, after the lapse of a few weeks or a few months, became dry and harsh. The ailment is a distinctive one, and is most commonly met with during the routine examination of the chest in school children, for it is comparatively seldom that it is severe enough for the mother to seek medical advice. Though not uncommon, it is much less frequently met with amongst the infants at welfare centres. It is a very persistent sign and may last through the life of the individual. As the hand is placed on the back of the shoulders one is struck with the rough, nutmeg-grater like feel of the skin. It is most common on the back of the upper arm and forearm, frequently extending on to the back of the shoulders. The extensor aspect of the leg is also not infrequently affected, but not so often nor to the same extent as the extensor surface of the arm. When well marked it involves the face and front part of the chest. Pathologically, there is an increase in the horny layer of the skin, with a tendency to atrophy of the deeper spiny layer of cells. The state of nutrition of the skin is markedly impaired, and there is a less succulent condition of the spiny cells, which change more rapidly than normal into the cells of the horny layer. It is usually associated with diminished activity of the sweat glands and scanty and coarse hair. The bends of the elbows, flexures of the knees, and the anterior surface of the abdomen, usually remain free. The skin is rough, dry, and dirty looking, and the natural lines of the skin are more marked than usual from the thickening of the epidermis. The scalp is often covered with fine, branny scales. This form of xeroderma is often greatly benefited by the administration of thyroid extract, and warm alkaline baths and oily inunctions are also useful. The hair in rickets tends to be thin, coarse and scanty. During the active stage of the disease the sweat glands over the head, face, and neck are often extremely active, while the skin of the rest of the body remains hot and dry. Later on, the

sweat glands show diminished action and the skin, as has been seen, tends to be harsh, dry, and scaly.

Diseases of the eye in rickets.

The condition of the lens and the rachitic state seem subjects very remote from each other, but a study of the disease known as lamellar or zonular or infantile cataract, also frequently but erroneously called congenital cataract, shows that the connection is a very direct one.

As far back as 1865, Prof. Johann Friedrich Horner, of Zurich (1831, 1886), first called attention to the connection between the occurrence of zonular cataract and certain dental deformities which he attributed to rickets. Horner was a busy practitioner, who did not court publicity and found but little time to write, but he was ever generous in giving his material to his students for the purposes of publication. In 1865, Dr. Davidson,* then a student at Zurich, embodied the views of Prof. Horner in an inaugural thesis, and showed definitely a clear relationship between lamellar cataract and certain rickety changes, notably in the skull and long bones, and in the defective laying down of the enamel of certain teeth. In 1883, M. v. Arx, another student attending his clinic, again expressed his teacher's views in an inaugural thesis, published at Zurich, "*Zur Pathologie des Schichtstaar's*," and gave the results of his extended observations.

Prior to 1865, Prof. Arlt, of Vienna, had noted that individuals with lamellar cataracts generally had a history of infantile convulsions. The observation was an accurate one, and the connection was explained when Horner proposed the view that both conditions are rachitic in origin. Horner's views were widely accepted on the Continent, but have only of late years been generally adopted in this country. This delay was largely due to the influence of Jonathan Hutchinson. The constant association between zonular cataract and a hypoplastic condition of the enamel did not escape his acute observation, and though he

* "*Zur Lehre von Schichtstaar*," Inaug. Dissert., Zurich, 1865.

recognised that the changes in the enamel associated with zonular cataract were entirely different from the hypoplastic changes met with in congenital syphilis, he was unable to accept Horner's view that they were due to rickets. He believed that the administration of mercurial powders for the treatment of convulsions in early infancy produced a stomatitis which affected the permanent teeth at the time when calcification was actively proceeding in the enamel.*

Hutchinson placed himself in communication with Horner, who forwarded him the results of his observations in an extended number of cases, and stated that the administration of mercury in infancy would not, in Zurich, explain the constant association of these two conditions.

Several other important papers have been written on the subject since that time.† Treacher Collins published some interesting observations on the distribution of rickets and lamellar cataract in Australia and Persia.‡ In Adelaide he finds, as the result of inquiry, that rickets is a rare disease and lamellar cataract is very infrequent; in Melbourne until lately, that is prior to 1895, rickets was rare but is more common now, though the severity is much less than in England, and lamellar cataract and hypoplasia of the teeth are both uncommon; in Sydney rickets is common, but lamellar cataract is less frequent than in England. In Persia, he notes, as the result of personal observations, that both rickets and lamellar cataract are rare.

Norman G. Bennett, in an important paper read before the Ophthalmological Society, in 1901, approaches the subject from the point of view of the dentist.§ He gives the result of the examination of twenty-six cases of lamellar cataract, examined with a view to obtaining an accurate

* "Imperfect Teeth and Zonular Cataract," by Jonathan Hutchinson, *British Medical Journal*, March 6th, 1875.

† "Zonular Cataract and Dental Deformities," by John B. Story, *Ophthalmic Review*, Vol. V, 1886, p. 277.

‡ "Lamellar Cataract and Rickets," by E. Treacher Collins. "Transactions of the Ophthalmological Society," Vol. XV, 1895; also "Trans. of 8th Session Australian Medical Congress," Oct., 1908; also "Trans. Ophthal. Soc.," Vol. XL, 1920.

§ "Ætiology of Lamellar Cataract," by Norman S. Bennett, "Trans. Ophth. Soc.," Vol. XXI, 1901.

record of the teeth affected. In four cases he notes there was no abnormality of dental tissue, while twenty-two showed a hypoplastic condition of the teeth, varying in extent but constant as regards the teeth affected.

Bennett remarks that possibly this may be an undue proportion, in view of the fact that being a dentist, ophthalmic surgeons would be more likely to send him cases which were of interest from the point of view of the dental defect. As will be seen later, however, in a series of thirty-five consecutive cases of lamellar cataract, which I have myself examined during the past year without any special reference to the teeth, or any other organ, I have found the proportion of cases of hypoplasia somewhat greater than that found in Bennett's observations.

A few well known points in the growth of the lens may be usefully recapitulated. The lens is developed as an invagination of the superficial epiblast, so that the nucleus corresponds to the epithelial surface. Unlike most epithelium, the surface cells cannot be cast off, so that the centre of the lens contains the oldest cells, a factor of importance in considering the pathological changes which the lens is likely to undergo. Just as the epithelium of the skin continues to grow throughout life, so the development of new lens fibres continues, though less rapidly, as time goes on. There being no blood vessels and no mesoblastic tissue, inflammation cannot occur, and all lens changes are essentially degenerative in their nature.*

Treacher Collins examined seven cases of lamellar cataract microscopically, and found three kinds of changes, of which he gave a *résumé* in a lecture at the Royal College of Surgeons, London, in 1894. The pathological changes correspond with three varieties of changes in the lens which can be observed clinically.

Firstly, there are fissures between the lens fibres, which may or may not contain a granular substance. It must be remembered that while the lens fibres are arranged concen-

* "The Pathology of the Eye," by J. Herbert Parsons. Lond., 1905. Vol. II, "Histology," Part II.

trically round the nucleus, they are also arranged like the segments of an orange. These fissures extend between these segments and are seen, on dilating the pupil, in the periphery of the lens, radiating from the centre like the spokes of a wheel, and are commonly spoken of as "riders." Slight conditions of this nature are quite common, much more so than is generally supposed, and as they produce no disability when very slight, they hardly excite any comment in the mind of the examining surgeon.

The second variety of change is produced as the result of small vacuoles, mostly round or oval, but in places elongated and beaded. Some of these spaces, whose average size is five micromillimetres, contain a hyaline substance which stains deeply with hæmatoxylin. This change corresponds with a uniform haze clinically.

Thirdly, there are larger vacuoles, measuring on an average twenty micromillimetres, mostly circular, with very irregular margins. They contain a granular substance which stains deeply with hæmatoxylin. Clinically these correspond to denser dots in the substance of the lens.

Examined by oblique illumination with the pupil dilated, the first appearance which strikes one is a tolerably uniform greyish opacity, which does not extend so far as the equator of the lens. This opacity is distinctly denser at the margin and the outer edge is usually well defined. It is situated in the layers surrounding the central core or nucleus of the lens. The superficial cortex is quite clear and the nucleus is usually but little affected. This grey discoid opacity is surrounded by a perfectly transparent marginal area. With the ophthalmoscope the disc appears black and sharply defined at the outer edge, diminishing in density towards the centre. The peripheral area shows a normal red reflex. Along the outer edge spokes of opacity, resembling the handles of a steering wheel, often extend slightly into the clear area. These are the so-called riders. A convenient method of examining these various conditions is to focus the ophthalmoscope on the opacity. This is most strikingly done with an electric ophthalmoscope, using a + 10 or + 12

lens before the sight hole, and working at a distance of from three to four inches. By this means fine early changes may often be seen which would otherwise be missed.

In lamellar cataract both eyes are almost always affected, though the changes may be more marked in one lens than in the other. Once formed, the condition, as a rule, is stationary, but in certain cases the opacity gradually increases in density. The formation of the cataract occurs at such an early period in the child's life that it is frequently spoken of as congenital, though the probability is that it is always post-natal in origin. This is borne out by the fact that the hypoplasia of the teeth, which is so constant a concomitant, is certainly post-natal in its origin, frequently beginning within a few weeks after birth. That lamellar cataract develops after birth has been seen by actual observation. Thus, Knapp records the case of a child who, at the age of two years and two months, had clear lenses, and who four years later had developed a large lamellar cataract in each eye.*

True congenital cataract is a rare condition, but many instances have been recorded. Thus, there may be a congenital cataract involving the nucleus of the lens while the periphery is healthy. Or the cataract may be total, involving the whole lens, which may be shrunken and degenerated, a condition often associated with congenital defects in the fundus. Not infrequently a circular spot may be seen on the back part of the lens, due to a persistent hyaloid artery, giving rise to a condition often inaccurately termed posterior polar cataract. These true congenital conditions have no association with defective laying down of the calcium of the enamel, and have no connection with rickets.

The main difficulty which has been raised in regarding lamellar cataract as a post-natal condition, is the fact that the diameter of the lens at birth may be considerably greater than that of the perinuclear zone in which the opacity occurs.

Bernard Dub† argues in this way in favour of the con-

* Knapp: *Archiv. of Ophthal.*, Vol. XXXV, 1906, p. 141.

† *Archiv. für Ophthalmologie*, Band XXVII, p. 26.

genital origin of lamellar cataract, and bases his calculations on measurements of the opaque zone of ten lenses obtained ophthalmoscopically during life, and a comparison of these measurements with foetal, infantile, and adult lens measurements.

Mr. Treacher Collins gives the result of direct measurements of the opaque zone in ten cases collected from various sources. Both observers come to the conclusion that the diameter of the opaque zone is hardly ever larger than that of the lens at birth. This implies that if the opacity is due to conditions of post-natal origin, either : (1) the condition after birth which gives rise to the opacity is capable of injuring fibres already laid down in the lens, as well as those in the course of formation ; or (2) that contraction of the lens nucleus is sufficient to account for the difference. Too much has been made of this difficulty, for although the chief growth of the lens has already been accomplished at birth, its condition is very different from that of the adult. No special provision in the adult is made for the nutrition of the lens, but in the embryo a more active growth necessitates a special mechanism for nutrition. This is provided by the vascular tunic of the lens, which invests the whole surface of the capsule on all sides. This vascular tunic is supplied by the hyaloid artery, which runs through the centre of the vitreous from the central artery of the retina. The tunica vasculosa reaches its maximum development in the seventh month of intra-uterine life, after which it begins to degenerate, and has, as a rule, entirely disappeared before birth. Occasionally, however, parts of this mechanism persist.

In the infantile lens no nucleus proper has been developed, though these fibres which are to form the nucleus are already deposited and can never be either cast off or replaced. The fibres are altogether more succulent and softer than in the adult lens, and changes continue to occur in them after the birth of the child, fitting them for their special optical function. It is, therefore, quite feasible that while the fibres now laid down show marked

vacuolation either in or between their fibres, the subjacent fibres which have been recently laid down may also suffer from the disordered nutrition before they have become properly consolidated. An actual contraction of the lens nucleus is also likely to occur, for, as already remarked, the fibres in this nucleus are soft and have not yet become sclerosed into the fibres of the adult nucleus. These fibres are the first laid down, and are the furthest removed from the nutrient supply, and contraction as the result of the failure of this supply can be readily understood. Mr. Treacher Collins agrees with this, and believes that as the result of rickets the part of the lens furthest removed from the nutrient supply shrinks, and in consequence of this shrinkage an opaque zone forms between the nucleus and the cortex from which it has retracted. This is also borne out by the fact that while the peripheral portion of the lens outside the definite line of the opacity is usually quite clear, the nucleus is only relatively clear, and generally shows some signs of degeneration. The degenerative changes in the lens fibres differ from those which occur in the enamel cells. In the teeth calcium is being actively laid down, either by or in the ameloblasts, and the part of the enamel affected is definitely marked out by a failure, either partial or complete, in the process of calcification proceeding at the actual time at which the rachitic state is operative. From the teeth one can definitely map out the time at which the morbid process begins to operate and the time when it has ceased to act.

Lamellar cataract, then, is held to be a characteristic sign of rickets; in consonance with the changes in the teeth, these alterations in the lens fibres occur after birth. The point is of considerable importance in considering the question as to the existence of foetal rickets.

During the year 1920, through the courtesy of the ophthalmologists attending the ophthalmic boards attached to the headquarters of the Ministry of Pensions, London region, I have had the opportunity of examining thirty-five consecutive cases of lamellar cataract, which came up for re-

survey in the ordinary routine examination of pensioners. There was no possibility of selection of cases, every pensioner with lamellar cataract being examined from the point of view of associated defect in the enamel of the teeth. In thirty of these cases definite hypoplasia of the enamel was present, that is in 85·7 per cent. In five cases the teeth were negative. It will be noted that these figures approximate very closely the results found by Mr. Norman G. Bennett in his series of twenty-six cases. This very constant association of hypoplasia with lamellar cataract clearly proves that both are produced by the same condition.

Very striking is the constancy of the nature of the change which occurs in the teeth. It has been already noted that there are several varieties of hypoplasia. The form associated with lamellar cataract is the very definite rachitic form of hypoplasia already described, and involves only the following teeth, viz., the central and lateral incisors, the tips of the canines, and part of the crown of the first molars, in both the upper and the lower jaws. The biting edges of the upper and lower incisors are almost always affected. Depending on the severity and the duration of the disease, the deficiency of the enamel extends to a varying extent upwards on the labial and buccal surfaces of the tooth towards the gum margin. As a rule, it is somewhat more extensive on the central incisors than in the lateral incisors. Generally, only the tip of the canine is involved. In the first molar tooth, Bennett states that he has usually found the deficiency of the enamel involving the whole tooth almost up to the gum margin. This has not been my experience, the part affected being usually the biting surface and not more than the third of the buccal and labial surfaces of the crown of this tooth. Though always involving both jaws, the condition is usually somewhat less extensive in the teeth of the lower jaw than in those of the upper jaw. As has been shown, this is the typical form of hypoplasia which has already been described as characteristic of rickets.

It must be carefully noted that this condition is frequently

masked by grinding down of the teeth. If the enamel is entirely absent and jagged dentine projects on the biting edge of the tooth, this is likely to be worn down, so that the biting edges become flattened, due to the wearing down of the exposed dentine, and a layer of blackened dentine is seen on the flat surface surrounded by a layer of enamel. (See Plate VII).

Hypoplasia, as has been seen, is a common form of defect involving, if all the varieties are included, some seven or eight per cent. of the population. The great majority of these defects are of the purely rachitic form. Lamellar cataract, on the other hand, is a comparatively uncommon condition, but the probability is that it occurs much more frequently than is generally supposed. If the lenses of one hundred cases showing definite hypoplasia were examined with the pupils dilated, the probability is that in a very fair proportion slighter forms of lamellar cataract, where the condition was only marked by a few "riders" in the periphery of the lens, having no effect on the vision, would be fairly commonly found. When these riders alone are present, they are not visible if the pupil is not dilated. It may be stated that the thirty-five cases examined among the discharged soldiers were all definite well-marked double lamellar cataracts, and were not of this very slight nature.

It is difficult to estimate the frequency of occurrence of lamellar cataract in the general population. Some recent figures, published by Dr. J. Kirk,* giving the result of the examination of 16,000 recruits, suggest that lamellar cataract of a degree sufficient to interfere with vision to the extent of 6/12 and over in each eye, occurs in about one in five hundred of the general population.

The question arises as to why hypoplasia and lamellar cataract should occur in certain cases and not in others. Their incidence is partly related to the severity of the disease. As already noted, though common to all classes of society, hypoplasia is more prevalent amongst the poorer

* "Sight Efficiency in the General Population," J. Kirk, *British Medical Journal*, July 8th, 1921.

classes of the community. In Australia, where rickets of a modified type is now fairly widely spread, hypoplastic conditions of the enamel seem to be almost unknown among the Australian born. Where hypoplasia is rare, Mr. Treacher Collins' observations tend to show that lamellar cataract is also very rare, so that apparently where the type of rickets is slight neither of these conditions is likely to arise.

Nyctalopia in rickets.

Certain other defects of the eye associated with rickets, though not perhaps in the very definite way that lamellar cataract is, may be conveniently noted. *Nyctalopia*, or night-blindness, unassociated with ophthalmoscopic changes, is now and then met with in out-patient departments among rachitic subjects. It is not apparently specially indicative of rickets, but is met with in many exhausting and nutritional diseases. The mother complains that the child stumbles over things as darkness comes on, and generally, if these children are taken into hospital, the condition improves rapidly under general hygienic treatment and good feeding. It is a prominent symptom in scurvy and in Barlow's disease. In 1880 Snell* reported on several cases in which this symptom was associated with a well-marked form of xerosis of the conjunctiva in children, and since then these observations have been confirmed; but this condition of xerosis does not seem to have any specific connection with the rachitic state. In view of the claim recently put forward that rickets is a deficiency disease, it is interesting to note that a severe and destructive form of xerophthalmia has been produced experimentally in rats, and has been ascribed to absence of a fat soluble factor.† In children, a similar and extremely rare condition was first described by von Graefe‡ as occurring occasionally in

* "Transactions Ophth. Soc.," Vol. I, 1880-81.

† "Report on the Present State of Knowledge concerning Food Factors (Vitamines)," 1919.

‡ A. v. Graefe, *Archiv. f. Ophthal.*, XII, Part 2, p. 250.

wretchedly delicate and marasmic children early in the first year of life. The condition tends to proceed to ulceration of the cornea and panophthalmitis. Both eyes are affected and the condition is usually fatal. The disease is known as keratomalacia and is very rare in this country, but, as Fuchs points out, it is fairly common in Russia at certain seasons. It is a form of necrosis and is not preceded or accompanied by acute inflammation. It is usually associated with diarrhoea, vomiting, marasmus, and extreme debility induced by chronic starvation. It seems to have no connection whatever with rickets.

The nyctalopia associated with rickets is usually a mild condition, and like many other rickety symptoms shows a marked tendency towards spontaneous recovery. Besides being common in scurvy and rickets, it prevails in some countries every year during Lent when no meat is eaten.*

Nystagmus in rickets.

Spasmus nutans, or nodding spasm, is a well known condition frequently associated with nystagmus and is commonly due to rickets. It is a rare condition and is characterised by irregular movements of the head, which may be from side to side or of the nodding variety. The movements may be continuous while the child is sitting up, but disappear when lying down and during sleep. Sometimes gesticulations with the arms follow the head movements. The symptoms usually begin suddenly, almost always in mid-winter, and usually last from three to six months, when they end in complete recovery. The condition was described by Henoeh † and also by Steiner.‡ Generally it begins between the ages of four and twelve months.

It has been met with not infrequently in America, where

* "Diseases of the Eye," by Edmund Nettleship, London, 1887, p. 240.

† "Lectures on the Diseases of Children," by Edward Henoeh; first published in 1876; 4th edition translated by John Thomson.

‡ "Compendium der Kinderkrankheiten," by Johann Steiner, Leipzig, 1878.

it is seen in bottle-fed and breast-fed babies, and in black and in white children.*

As this condition almost invariably ends in recovery, it is important to differentiate the nystagmus which occurs in nodding spasm from the more serious forms of nystagmus due to congenital cataract, tumours of the brain, hydrocephalus and hereditary ataxia. John Thomson † has pointed out several peculiarities present in this slighter form of the disease. Thus, it is often unilateral instead of being nearly always bilateral. Often the movement is vertical or rotatory instead of being nearly always horizontal, and the direction of the movement may be different in the two eyes. In the rotatory form the excursion of the centre of the cornea is much greater than usual in rotatory nystagmus.

In ordinary horizontal nystagmus, the anterior-posterior axes of the two eyes remain parallel to one another, that is, it is conjugate in its character, whereas in the variety associated with nodding spasm the eyes incline towards and away from one another, that is, it is a convergent nystagmus. The chief causes of this condition, Thomson believes, are insufficient light and rickets.

Myopia and Rickets.

An association between these two diseases is suggested by the fact that the one follows the other, and that both seem to be connected with the same conditions.

The ordinary explanation of the origin of myopia is, that during convergence on near work the extra-ocular muscles, notably the internal rectus and the superior oblique (Stilling), exercise undue pressure on the eyeball, thereby increasing the tension outside the eye and causing a lengthening of its antero-posterior axis. This explanation is felt to be very inadequate, and does not explain many

* Miller: "Three Cases of Head-Nodding," "Trans. Amer. Ped. Soc.," New York, 1900, XII, 72-80. August A. Eshner: "Nodding and Rotatory Spasm of the Head with Nystagmus in Rachitic Children," *Archiv. of Pediatrics*, Vol. XVIII, 1901, p. 598.

† "Guide to the Clinical Examination and Treatment of Sick Children," by John Thomson, M.D. Edinburgh and London, 1908.

marked cases occurring in young persons who develop high degrees of myopia before they have begun to use the eyes for near work ; nor does it explain the fact, that although all children are educated in much the same way myopia only develops in a few. Sir Arnold Lawson found myopia in five per cent. of all children under fourteen years of age, as a result of the examination of 2,000 London school children.*

High myopia is common among peasants as well as among the educated classes, and the probability is, that while near work may be harmful in myopia, it is seldom if ever, by itself, a cause of the disease.

The shape of the eyeball depends chiefly on its firm, resistant outer coat, which is formed by the strong, opaque, fibrous structure, the sclera, with the transparent forepart, the cornea. Around the posterior two-thirds of the eyeball there is another supporting tunic—the capsule of Tenon. The cornea and the front part of the sclerotic are comparatively unsupported from the outside, and would tend to bulge forwards if they were not efficiently supported by the lens with its capsule and ligament, which help the cornea to resist forward pressure.

Now many facts show that myopia is essentially associated with debilitated states of the individual. It is a disease of modern civilisation. It is seldom congenital, but develops during the period of active growth of the body, manifesting itself between the ages of from four to sixteen years, most commonly about the period of adolescence. It is more prevalent in towns than in the country. Unlike highly civilised nations, savage communities are but little prone to the disease. During wasting illnesses it is apt to increase, and it diminishes as health and vigour return. The generally accepted explanation maintains that vigorous muscular action required in the act of convergence is the cause of the increase in length in the myopic eye, whereas all the conditions showed a marked tendency to debility rather than to continuous and excessive muscular action.

* " Diseases and Injuries of the Eye," Arnold Lawson, London, 1903.

In health, the fundus and the sides of the eyeball are well braced up by the extra-ocular muscles, and the fundus is supported by the fat and loose areolar tissue which lies between it and the orbit. All the muscles together combine to maintain this uniform healthy tension. In enucleation of the eyeball, when the long muscles of the eye are divided, the globe starts forwards owing to the sudden release of the backward pressure against the elastic pad lying between the fundus of the eyeball and the back of the orbit. Much the same condition arises in cases of extreme muscular debility. Rickets plays a formidable part in the production of these debilitated states, and like scoliosis, flat-foot, and knock-knee, myopia may arise as the sequel of the persistence of a debilitated muscular state long after the active stage of the disease has passed.

But yet another factor has to be reckoned with. Normally, the sclerotic coat is thinner in the young child than in the adult, and in rickets, and other debilitating states, notably after measles and whooping cough, it tends to be softened and is rendered still more attenuated as a result of malnutrition. In the convergence on near work, the pull of the ciliary muscle on the choroid, and through this coat on the sclerotic, may have some slight action in the production of myopia, but it is only likely to do so when the supporting extra-ocular muscles have lost their tone, and when the sclerotic coat is thinned and weakened as the result of debilitating disease.

As has already been shown, alterations occur in the bony orbit as a consequence of the rachitic state, and the question arises if such changes have an influence on the shape of the contained globe.

Stilling* advanced the theory that lengthening of the eyeball is due to pressure of the superior oblique muscle, and that the action of this muscle varied with the configuration of the orbit, and the position of the trochlea, the pulley through which the round tendon of this muscle plays. If

* "Ueber Schädelbau und Refraction," Herr Stilling (Strassburg), 7th Internat. Ophth. Cong., 1888, p. 97.

the trochlea were below the normal level, he held that the muscle exerted much pressure on the eyeball, and in support of his view, he maintained that in myopia the orbit is broad and low, whereas in hypermetropia and emmetropia the orbit is relatively high. This, however, is not an explanation capable of general application. Among many broad-faced peoples myopia is rare.

Others have maintained that as a result of the softening of the bones which occurs in rickets the weight of the anterior lobes of the brain acts on the orbital plate of the frontal bone, producing depression of that plate and compression and flattening of the globe of the eye.* In this way, it is argued, an elongation of the long axis of the eye may be produced by an excess of curvature of the cornea and of the lens, and an increase in the depth of the anterior chamber, or by a distension of the posterior part of the sclerotic. Such theories lose sight of the fact that the globe of the eye is a comparatively small structure contained in a large cavity, which could accommodate with ease a globe of much larger circumference. In some extreme cases of advanced hydrocephalus there is evidence of such compression of the eyeball, and there may be a certain degree of proptosis of the eye, with the characteristic exposure of the sclerotic between the iris and the lids. But even in hydrocephalus myopia is not a common feature, and severe degrees of hydrocephalus are not usually a result of the rachitic state. The tendency of rickets is, as has been seen, to elongate the orbit from above downwards rather than to produce flattening.

In this way myopia is linked up with a large class of morbid conditions produced by the rachitic state, viz., scoliosis, pes planus, and genu valgum, defects which are dependent on loss of muscular tone, and softening and relaxation of fibrous and ligamentous structures. The muscular debility and general loss of tone continue long after the active stage of rickets is passed, and the disease has under-

* "Myopia and Astigmatism in Rickets," M. Hauchcorne, *La Semaine Médicale*, 1901, p. 159.

gone partial cure. In inducing myopia these conditions act in two ways: (1) by loss of tone of all the extra-ocular muscles which act on the eyeball; (2) by interference with the integrity of the great supporting tunic of the eye, the sclerotic coat, owing to thinning and softening. As already noted, these conditions may be induced by attacks of prolonged and debilitating disease, but among our large town populations rickets is by far the most widespread influence producing profound debility in the infant and the growing child. I have myself known definite and permanent increase of myopia to occur as a result of the depressing influence of typhoid fever.

Another condition of the eye may be shortly mentioned in association with rickets, though the connection is indirect. Corneal ulcer in the young child is rare, but the condition known as phlyctenular, or formerly strumous ophthalmia, is common at the age of three or four years. It is a conjunctival condition primarily attacking Bowman's membrane, and may, if neglected, lead to opacity seriously interfering with vision. It may follow measles and scarlatina, and is often the result of direct infection through the nasal duct from unhealthy conditions of the naso-pharynx, so frequently associated with mouth breathing and the rachitic state.

CHAPTER XVII

The Nervous System in Rickets

It has long been recognised that certain states of the nervous system are very definitely associated with rickets. It is of considerable interest and importance to consider the rachitic state as it affects various definite structures, apparently quite remote from each other and dissociated in function, which are yet clearly linked up embryologically, in that they are developed from the same embryonic layer. No structures would seem at first glance to be more unlike than the enamel of the teeth, the skin with its appendages, and the lens of the eye; and yet it has been shown that changes along definite lines occur in each of these structures, which are frequently definitely associated with each other, and all of which are due to one common cause—rickets.

The consideration of the diseases of the central nervous system associated with rickets presents more difficulty. There are no gross changes in this system exhibiting themselves readily to the naked eye, as in the cases of the enamel of the teeth and the lens. But the signs and symptoms produced by abnormal action of the central nervous system in rickets are so definite, and so well defined, that it may reasonably be inferred that actual structural changes occur in the very nerve elements themselves. It has been usual to speak vaguely of an increase in the connective tissue element of the brain in this disease, but the probability is that the essential alteration is much more subtle and affects the actual neurons. The fact that the characteristic nervous diseases which result from rickets are frequently accompanied by definite naked eye alterations in other structures derived from the same embryonic layer lends corroboration to this view. Thus, lamellar cataract is nearly always accompanied

by convulsions in infancy; when the second teeth are erupted, 85·7 per cent. of these cataract cases show a definite form of hypoplasia affecting the enamel laid down during the first two years of the child's life.

In tetany, another very characteristic defect of the nervous system usually due to rickets, Fleischman noted the constant presence of hypoplasia affecting the permanent teeth.*

The outer or ectodermic layer of the blastoderm gives rise to the following structures: (1) the enamel organ which grows as a ridge from the epithelium of the oral cavity into the cellular embryonic connective tissue; (2) the epidermis and its appendages, including the hair and nails; (3) the most important functional parts of the sensory organs, such as the lens, and the optic, auditory and olfactory nerves; (4) the whole of the central nervous system, including not only the central organs (brain and spinal cord), but also the peripheral nerves and sympathetic. In rickets changes may, and frequently do, occur in all these structures, and the factor responsible for their production is the aberrant action of the glands of the endocrine system, induced in response to the conditions of altered environment which are responsible for the disease.

The gross rickety changes which occur, such as hypoplasia of the enamel, harsh and dry skin with coarse and scanty hair, and lamellar cataract, are easily recognised by the naked eye. The pathology of the nervous system is more elusive, dependent as it is on the intimate structure of the neuron; but when it is found that there is a constant association of certain nervous symptoms, such as epilepsy, tetany, spasmodic nutans, and laryngismus stridulus, with rickets, and especially when certain of these symptoms are definitely related to visible and well-marked changes in the other epithelial structures, it seems reasonable to conclude that these nervous diseases are due to structural alterations in the nerve elements themselves and are produced by the same cause.

* Fleischman: "Beziehungen zwischen der Tetanie und der Entwicklung von Defekt-bildungen des Zahnschmelzes." *Mitt. d. Gesellsch. f. inn. Med. u. Kinderh.*, in Wien, 1908, VII, 182-184.

Convulsions in infancy and their relation to epilepsy.

In the new born child, as is well known, the lowest level centres of the nervous system, that is, those of the spinal cord, medulla and pons, are relatively more fully developed than the higher brain centres, which as yet possess very little of that controlling influence which they speedily acquire as the child grows. Thus certain simple reflexes occur with great ease in the young infant. The association between sensations of hunger and the seventh cranial nerve are easily understood, establishing a ready reflex to allow of the action of the buccinators and the other strong sucking muscles. In the young infant a few weeks old slight attacks of flatulence after a meal frequently produce rippling spasms passing over the face, especially during sleep, elevating the angles of the mouth into the appearance of a smile or drawing the face to one side. This occurs under perfectly normal circumstances with a healthy infant. If prolonged or somewhat more severe, the third cranial nerve may be thrown into action and the eyes of the child may be turned up, exposing the whites, or the eyebrows may be elevated and the eyelids frequently twitch. Mendel, supported by Tooth and Turner, has shown that there is a connection between the nuclei of the oculomotor and the facial nerves, and the probability is that these movements are the result of simple reflexes which do not reach further than the nuclei, and which have no tendency to become generalised into convulsions. Flatulent attacks produce these reflex actions in the seventh and third cranial nerves in perfectly healthy infants, but when the child is a few months old they are less easily produced.

This reflex excitability is recognised to be perfectly natural in the healthy infant, and its absence may in itself be a sign of disease. Thus, in children reduced to a cachectic state by malnutrition consequent on insufficient or unwholesome diet, apart altogether from the rachitic state, this excitability may be greatly reduced.

Eustace Smith emphasises two facts in these debilitated

children : (1) that reflex convulsions are rare, owing to the insensibility of the nervous system concerned in the production of reflex movements so characteristic of the healthy child ; (2) acute diseases in these children have a character all their own. They are more insidious and have a slower course, and give rise to fewer symptoms ; often they end suddenly and unexpectedly in death.*

Very different is the state of affairs found in rachitic children. They may be wasted and debilitated, but on the other hand they may be fat, plump, and well nourished. In either case the child is likely to exhibit a false appearance of placidity, whereas the reflex excitability is extreme and laryngismus stridulus and convulsions are very common. Healthy infants do not easily become convulsed unless the stimulus is strong, and in the large majority of children who suffer from convulsions up to the age of three years the signs of rickets are present. Convulsions chiefly occur during the first six months, and four-fifths of all cases occur before the end of the second year. Normally the gastrointestinal tract of the infant easily rids itself of excess, either by the act of vomiting or by increased intestinal peristalsis. It is not so easy as is often stated, to overload the system of the young infant. Provided other conditions are healthy, nature fortunately allows for a large margin of error in feeding. But in the rickety child, a solid curd in the stomach or bowels may excite a stimulus over a wide area, and many nerve centres may be thrown into activity. The facial muscles twitch and the eyes roll upwards. Frequently there is spasm of the glottis and of the respiratory muscles. The hands may be clenched and the legs drawn up, to be followed by a clonic spasm of all the muscles of the extremities.

Dentition may be an exciting cause of convulsions. The eruption of the teeth is usually spoken of as a perfectly natural process, devoid of symptoms in a healthy infant. This is far from being the case. The healthy breast-fed

* "The Wasting Diseases of Children," by Eustace Smith, London, 1878.

infant frequently shows the gums swollen, hot and dry, as the result of the rapid descent of the teeth, and no one who has watched the gum slowly receding over the advancing tooth can doubt that it causes considerable constitutional disturbance. In health the irritation of the trigeminal nerve induces the child to bite at every object it can raise to its mouth, but in the rachitic child the reflex act may spread much more widely, and often ends in general convulsions. Not all cases of convulsions are rickety; scarlatina is very liable to be ushered in by fits, as also are diseases which cause high temperature, such as pneumonia. The onset of meningitis and the acute stage of infantile paralysis may also be marked by convulsions. But in the great majority of infants and young children who suffer from spasmodic and convulsive states, rickets is the essential cause which renders the nervous system liable to give an excessive response to what is often a comparatively small stimulus. Out of fifty cases of laryngismus stridulus, Dr. Gee found that forty-eight were rickety, and of these nineteen had general convulsions. In 102 children in whom general convulsions occurred, forty-six were rickety—that is about half; * the probability is that the number of rachitic cases among these last children is considerably underestimated.

The relationship of infantile convulsions to the onset of epilepsy is a matter of the greatest importance. The majority of convulsive seizures in infants are single, but in certain cases they are repeated and may recur over a long period. While it is probably true that the greater number of children who suffer from convulsions in infancy lose the tendency to these seizures as they grow older, it is undoubtedly true that in a large percentage the fits continue, or recur after a certain interval, and pass into the disease known as true epilepsy. The two conditions in these cases are identical.

Jenner held this view, and Gowers found that in 12·5 per cent. of cases of chronic epilepsy, there was a history of the

* "St. Bartholomew's Hospital Reports," Vol. III, 1867.

fits commencing during the first three years of life, while in 5.5 per cent. they occurred during the first year.

Osler, in 460 cases of epilepsy in children, noted the time of onset in 428, as follows :—

1 to 5 years	...	...	...	229
5 to 10 „	...	...	...	104
10 to 15 „	...	...	...	95

These figures illustrate in a striking manner the early onset of the disease in a large proportion of the cases.

Much weight is often laid on the exciting causes of fits in children, such as gastro-intestinal irritation and teething, but their importance is apt to be much exaggerated. Fits would not occur in healthy children under such circumstances. The important point to remember is that the exciting cause acts on a prepared territory, and once established, as in most cases of chronic epilepsy, no such cause for the actual convulsion can be discovered. The nerve cells have become highly unstable, and there is apparently an actual degenerative change in the neurons themselves responsible for the disease. It is now generally believed that these fits may have their origin at three levels :—

1. The lowest level situated in the spinal cord, medulla and pons. Laryngismus stridulus is usually supposed to be produced at this level.
2. The middle level, consisting of the motor centres in the Rolandic area. In this, the Jacksonian form of epilepsy, the convulsion begins in certain muscles and may only involve a certain group without becoming generalised. Some of these cases are due to gross lesions in the brain, but in many no such cause is to be found.
3. The highest level, situated in the frontal and occipital regions of the cortex. Such cases are apt to be exceedingly complex, and the fit is usually preceded by an aura followed by a widespread generalised convulsion.

What the nature of the changes in the brain cells which follow on the rachitic state is, it is at present impossible to say, just as it is in most of the so-called idiopathic forms of epilepsy. In rickets, error in the calcium metabolism is a prominent feature of the disease, and the association of myetetic and nervous irritability in such cases is now well

known. There may be no want of calcium in the system, indeed, it may be excreted in excess in the urine, but there is a want of capacity on the part of the tissues to make use of the calcium which is present. It can readily be understood that the continued deprivation over a prolonged period of any one element necessary for the proper nutrition of the nerve cell may easily produce permanent and serious damage in its structure. The importance of the relationship between epilepsy and rickets lies in the fact that, if the connection is proved, it brings a large number of these grave conditions within the class of preventible diseases, for rickets is pre-eminently one of the maladies capable of mitigation and cure, and with reasonable care its incidence might be wholly prevented.

The hereditary factor in epilepsy is one on which opinion varies greatly, and of late years the tendency has been to discount its influence. Thus, Osler * notes that the French physicians, notably Marie, take strong grounds against heredity as an important factor. In a series of 126 cases, Osler himself found that in thirty-two, there was a family history of nervous derangement of some sort, but that there were only two, in which the mother had had epilepsy, and not one in which the father had been affected.

The probability is that the proportion of rachitic and therefore preventible cases of this very grave malady may ultimately prove to be very large. It would be of much interest to compare the rate of incidence of epilepsy in countries such as New Zealand and Australia, where rickets is either rare or present only in a mild form, with that which occurs in Europe, where rickets is prevalent.

Laryngismus stridulus in rickets.

Laryngismus stridulus, on account of its frequency and its alarming nature, is one of the most important of the convulsive attacks of infancy. It tends to occur early, and is not so likely to appear after the age of three years, though it may do so up to the age of seven. This condition is

* *Ibid.*, p. 1094.

characterised by paroxysms of difficult breathing, which come on suddenly and may be so severe that they end in suffocation, though usually they end in recovery marked by a deep crowing inspiration. Frequently the face is pale, but may become dark, swollen and congested. The first attack generally comes on at night, the child waking suddenly from sleep and making as if it were about to cry. But instead of inflating the lungs, repeated spasmodic attempts are made to fill the chest, between each of which a squeaking sound is made. In a few seconds the attack passes off and the child cries itself to sleep. The attacks may not recur for some considerable time, but if the rickety state is continued and severe, they tend to come on by day as well as by night, and are brought on by the most trivial circumstances, such as surprise or fright. The attacks, which at first were quite short, are prolonged, and may last for a quarter of an hour or longer. Usually the infant is obviously in poor health, but in fat rickets it may look quite healthy and may seem perfectly well in the intervals.

When the attacks are severe, carpo-pedal contractions are apt to occur, the thumbs being bent into the palms of the hands, while the feet and toes are bent in the position of equino-varus. Later, general convulsions may supervene, and in these cases death is not infrequent following an attack. Cranio-tabes, first described by Elsässer, was, as has already been noted, held to be responsible for most of the convulsive seizures of infancy. This received the support of Kassowitz ; Jacobi found this condition of the skull in an extraordinary number of cases of children suffering from laryngismus stridulus, noting softened areas of such small extent that they would not be appreciable to most observers. As a general rule, pressure on these softened areas is well borne, and there is probably no direct association between the convulsive attacks of infancy and cranio-tabes. Laryngismus stridulus is probably due to malnutrition of the nerve cells which subserve the function of respiration in the lower level centres of the brain, and, as was suggested in speaking of epilepsy, the likelihood is that there is an

actual structural alteration in the neurons themselves. Post-mortem examinations in fatal cases are usually negative, for the distended state of the meningeal veins and the presence of serous effusion under the arachnoid and within the ventricles of the brain are lesions produced by the mode of death. Enlargement of the thymus has been cited as a cause of laryngismus stridulus, and though it is not a common cause it may be present, and the possibility of the existence of the associated condition of status lymphaticus should be borne in mind. This is the condition described by the older writers as thymic asthma.

Tetany in Rickets.

Tetany is a well known disease of the nervous system, which is commonly associated with rickets in the young child. Fischl found that sixty-three per cent. of his cases were rachitic. It is characterised by marked hyperexcitability of the neuro-muscular system, and is associated with bilateral spasms of the extremities, which may be continuous or intermittent. In laryngismus stridulus, as has already been seen, a form of carpo-pedal spasm is a frequent accompaniment, and is usually an early manifestation of this disease. As a rule it occurs early, and is much more common before three years than after. Griffith found that sixty-eight per cent. of cases occurred before the end of the second year. It is interesting to note that tetany may occur in the adult, when it is usually connected with the reproductive functions. Thus, it may occur in a mild form in girls about the age of puberty; or it may supervene during pregnancy, but it is most likely to begin during the period of lactation, especially if prolonged, a condition named by Trousseau "*nurses' contracture*." It may follow successive pregnancies.

Tetany also occurs in epidemic form, particularly in spring and in the winter. It may follow infections such as typhoid fever and measles. Dilatation of the stomach is a condition which has been noted fairly frequently in tetany, and is usually associated with a more severe form of the

disease and a higher mortality. The prognosis, as a rule, is very good in ordinary rachitic cases.

It is now well known that tetany may follow operations on the thyroid. Since the discovery of the parathyroid glands by Sandström, in 1880, the nature of this artificially produced condition has been made much clearer.

The term "tetania strumipriva" is applied to the form of tetany following operations on the thyro-parathyroid apparatus. It is now fairly well established that this condition follows removal of the parathyroids, and is not likely to occur when the thyroid is removed and the parathyroids are left intact. In animals, partial removal of the parathyroids may lead to nutritional changes, such as emaciation, apathy, and roughening of the coats. Complete removal leads to trophic and nervous changes, ending in death in from three to five days, though this may be delayed. There is great excitability of the nervous system, leading to muscular twitchings over the whole body. Fibrillary twitching of the muscle fibres of the tongue is apt to be present, and tonic contractions of the facial muscles and of the laryngeal muscles producing stridor may supervene. Acute tetanic spasms are likely to follow, ending in death. This disease has been checked by transplantation of parathyroid tissue. MacCallum's experimental observations would seem to show that some change takes place in the blood. The exact nature of the chemical change which occurs has not been established, but it may be of two kinds: (1) there may be an active poison in the blood; Noel Paton has suggested an intoxication produced by guanin compounds; (2) something is withdrawn from the blood which normally exerts a moderating and quieting influence on the nerve cells, leaving them unbalanced and hyperexcitable.

MacCallum * has suggested as a plausible working hypo-

* "On the Relation of the Parathyroid to Calcium Metabolism and the Nature of Tetany," by W. G. MacCallum and C. Voetglin. *The Johns Hopkins Hospital Bulletin*, Vol. XIX, Baltimore, 1908. "The Function of the Parathyroid Glands," W. G. MacCallum. *The Journal of Amer. Med. Assoc.*, August 3rd, 1912.

thesis that withdrawal of calcium salts from the cells occurs in this disease, leaving them hypersensitive. There is a good deal of experimental evidence to support his hypothesis, and the clinical study of rickets in connection with changes produced as the result of inactivity of the thyroid and parathyroid apparatus, lends plausibility to a view, which, if true, is capable of wide application.

It is a well known observation that withdrawal of calcium from a cell, leaving a greater proportion of sodium and potassium, renders the cell hyperexcitable. MacCallum believes that there is a striking reduction in the calcium of the blood in tetany, and his statement has been confirmed by other observers. The injection of calcium salts into the blood has an immediate soothing effect on the experimentally produced condition, and in children suffering from the disease, the administration of calcium lactate in five to fifteen grain doses has proved very efficacious. The conception that rickets is due to deficiency of calcium in the food is a very old one, which, however, does not agree with the fact that in the urine there is frequently an excess of calcium in this disease. Neither is the addition of calcium to the diet a certain method of ameliorating the condition. MacCallum's observations suggest that there is an incapacity of the tissues to utilise the calcium which is present, due to the loss of some internal secretion which is normally passed into the blood. As more is learnt about the action of the glands of internal secretion, the more is one diffident in ascribing a definite disease to any one gland. But it would seem justifiable to say that the thyroid apparatus, including under that term the parathyroid glands, exerts a controlling influence on calcium metabolism. It is obvious, from what is known of the action of the thyroid in myxœdema and cretinism, that it tends to hasten tissue metabolism. Hutchison* points out that its secretion hastens the life history of the cell. Cell division occurs more rapidly and the cell reaches maturity more rapidly.

* "The Pharmacological Action of the Thyroid Gland," by Robert Hutchison, *Brit. Med. Journal*, July 16th, 1898,

In myxœdema, on the other hand, many of the cells never reach a mature stage and the subcutaneous tissue becomes filled with cells in an embryonic stage, and when the old hairs fall out the cell division, which should lead to the formation of new hair, does not take place. The thyroid exerts its beneficial influence by hastening the life history of the cell. This explains its action in backwardness of growth in school children, and the good effect it often produces in such conditions as psoriasis and in dry skin and in ichthyosis.

Removal of the thyroid or impairment of its action tends to produce reduction of temperature, and decreased intake of oxygen, and diminished output of carbonic acid. Associated with this change, there is a lymphatic hyperplasia in rickets, such as is commonly found where there is a conservation of metabolism. Naturally, this diminished metabolism leads to partial, or more or less complete, arrest of the processes of nutrition and growth. These are points of the first importance in considering the origin of rickets and the adaptation of the infant to the inimical environment which surrounds it in slum dwellings in large industrial centres.

Tetany seems to be more common in Europe than in England, and is not common in the United States, though the condition has been carefully studied in America, and many cases have been described. In laryngismus stridulus, convulsions, and epilepsy, there seems to be instability and a tendency to irregular discharges in the actual nerve cells themselves situated in the various brain centres. In tetany there is also a marked irritability in the peripheral nerves. The symptoms of tetany are characterised by spasmodic contractions or cramps in the legs and arms, which are the parts most commonly affected. The child does not lose consciousness and the cramps are associated with a good deal of pain. The arms are pressed against the thorax, the elbows are flexed, the thumbs are bent into the palms, and the fingers are tightly flexed over the thumb. The fingers are approximated and are in the position pro-

duced by contraction of the interossei, that is, they are flexed at the metacarpo-phalangeal joints, while the interphalangeal joints are extended, producing the so-called obstetric position of the hand. The lower limbs may be adducted with the thighs flexed on the abdomen and the legs on the thighs. Usually the feet are in the position of equino-varus, that is, the ankle joint is extended, and the soles of the feet are turned inwards with the toes bent. After the contraction has lasted some time there is often œdema over the dorsum of the foot. (Koplik.)

The irritability of the peripheral nerves is responsible for the production of two well known signs in tetany, viz., Chovstek's sign, in which tapping over the distribution of the facial nerves produces well-marked spasm of the muscles supplied by the nerve, and Trousseau's sign, in which pressing over the main nerve trunk of the limb produces an attack of the spasmodic contractions characteristic of the disease. There is also increased electrical excitability of the nerves. Erdheim's observations are of interest in connecting up tetany with failure of the calcium metabolism. He found that in rats with chronic tetany the incisor teeth become soft and break off, because no calcium is deposited in the dentine, and fractured bones fail to unite because no callus is formed.

Grouping these several conditions—convulsions, laryngismus stridulus and tetany—under one heading, the various theories as to their causation may be summarised as follows :—

1. Elsässer's view that it is due to pressure on the brain through softened areas in the cranial bones, due to cranio-tabes, is not now considered a factor of much importance.
2. Kassowitz believed that in tetany rickets first produced an irritable condition of the nervous system associated with congestion, and that toxic products from the polluted atmosphere of small, overcrowded, and badly ventilated rooms inhaled through the lungs, excited the already over-sensitive nerve cells to irregular discharges.
3. Intestinal toxæmia has been held by many to be the essential agent in producing these states. As already

noted, the association of gastric-dilatation and a certain severe form of tetany lends colour to such a view, but in a large proportion of cases there is no evidence of any irritation in the gastro-intestinal canal, and in many cases, where there is marked gastro-intestinal disturbance, tetany does not supervene. Escherich has observed that tetany is especially apt to occur in very fat children who are constipated and show but little evidence of bony change—a very definite and well recognised type of soft rickets.

4. Disturbance of the calcium metabolism has been blamed for the production of the spasmodic diathesis, and two diametrically opposed views have been put forward. Stoeltzner maintains that there is a condition of calcium intoxication due to an excess of calcium salts in the system. Supporting his view, several German investigators have maintained that the use of cow's milk, owing to the excess of calcium contained, may be a factor in producing this disease. The gastro-intestinal mucosa is one of the chief emunctories dealing with the excretion of calcium, and it has been suggested that the excess of calcium may be due to retention owing to some defective state, possibly inherited, of the mucosa. Stoeltzner holds that there are two varieties of tetany, the one—infantile tetany—being due to excess of calcium, while the other is due to injury or disease, or removal of the parathyroids—tetania strumipriva. The most recent view is that based on the work of MacCallum and Voetglin, already referred to, that the spasmodic state is due to thyroid and parathyroid insufficiency. The fault does not lie in any deficiency in the intake of calcium, which is usually ample, but in an insufficiency or deprivation of some internal secretion, which renders the tissues incapable of utilising the calcium which is available. This last view is the one which fits in best with the experimental evidence, and accords with the metabolism of the rachitic state which is found clinically.

Some aspects of the general development in rickets may be here touched upon.

The delay in walking and in speech has already been referred to, and not infrequently the prolonged inability to walk, or the backwardness in speaking, first induces the mother to seek advice.

During the active stage of the disease, the child, instead

of rejoicing in activity, is unduly placid. But this placidity, as has been shown, is only apparent.

Mental development in rickets.

Incontinence is a symptom that is of frequent occurrence in rickets, and it is of interest to note that thyroid treatment is frequently successful in these cases. The mental progress of the child is slow, and this is especially shown in speech, as already noted. Defective forms of speech are frequent; lalling is common, and stammering and stuttering are apt to develop later. The child has difficulty in picking up new words.

Mental state at time of entry into school.

At school age the rickety child is distinctly backward when compared with the normal child. The backwardness may last for some years, and then somewhat suddenly the child often makes a rapid advance, noticeable to both parents and teachers. There is, as it were, a sudden intellectual awakening. This is characteristic of the mentality of rickets. Typically, the child at school age is dull, and its powers of attention are poor, rendering it the despair of its teacher. By the fourth or fifth year of life the child is beginning to improve physically and to become more active; but the mental improvement does not begin till somewhat later. The mother frequently makes the statement that all her children begin to pick up wonderfully about the age of seven, an observation which is quite consistent with the facts in the great majority of cases.

Mental condition in later school life.

In the slighter forms of rickets, and especially when the natural surroundings become more favourable, the child's mental condition may return to the normal, and no permanent damage seems to be done. But in a large number of cases the sudden progress which the child makes only carries it to a certain limit still below the normal, so that its capacity is only equal to that of a child two or three

years younger. The child's powers of attention and concentration remain poor, the mental response is much delayed, and frequently a question will have to be repeated several times before the child grasps what has been said. In the ordinary work of the class the child remains a distinct drag. A judicious selection of such children, and the placing of them together in a class where they can be put to modelling in the round, drawing with coloured chalks, and, in the case of girls, housework, is often followed with the happiest results. For the first time the child does work which it can really do well; a few weeks at such work, where the hand assists the brain, will often convert a dull, listless child into one that is bright and alert. Its self-respect is increased as it finds that at certain kinds of work it can hold its own. The training of the mind through the muscular sense is peculiarly well adapted to this type of child. When the mental condition remains below the normal, the child in severer cases is apt to be moody, and is not infrequently vicious and spiteful, and uncertain in temper. Such cases are especially troublesome, as they are often associated with children of younger age than themselves owing to their slow progress through the standards. In many cases the early struggle against adverse circumstances leads to a certain infirmity of purpose which persists through adult life, and probably accounts for a good many half failures in adult life.

Dividing the eight hundred rickety children out of one thousand examined in the East end of London into three classes—bright, average, and backward, it was found that :—

11	per	cent.	could	be	considered	bright.
64	”	”	”	”	”	average.
25	”	”	”	”	”	backward.

The very universality of the condition probably makes one content with not only a much lower general standard of mental development, but also with a lower standard of growth than might legitimately be expected if the environment of the child were such as to allow of its full mental and physical development. It must be remembered that this

arrest of development is permanent ; if a systematic examination were made of the mental development of the adults in our crowded cities and slum areas, a large proportion would be found who had never attained a mental development beyond that of a child of twelve years.

CHAPTER XVIII

Affections of the Blood and of the Lymphatic System in Rickets

Changes in the blood in rickets.

THERE are several fallacies to be guarded against in an examination of the blood in infancy. The ordinary standards for blood counts do not apply where many of the features of pre-natal blood formation still persist. Thus, nucleated red blood corpuscles are not uncommon normally in the young infant. Megaloblasts, if present in the adult in any appreciable number, are usually indicative of pernicious anæmia, but in infancy their presence seems to be of comparatively little importance. Pernicious anæmia is excessively rare in children under the age of ten, if it exists at all. Leucocytosis is common in infancy, and 20,000 to 60,000 leucocytes per cubic millimetre are frequently met with and the presence of myelocytes is common. Another possible source of error lies in the fact that rickets is an exceedingly common disease, so common indeed that in the hospital and dispensary class of patient it is probably difficult to obtain a normal standard as a control. It may well be that the tendency to leucocytosis in infancy is a widespread reaction against a vicious environment and has a definite protective influence, though Cannata* states that the phagocytic action of the leucocytes in rickets is low.

Clinically, there is little doubt that slighter forms of anæmia are fairly common in uncomplicated rickets. On the other hand, it is equally certain that fairly severe rickets may be present without any evident signs of anæmia ; there

* S. Cannata. " Il potere fagocitario del Sangue nel Rachitismo Rivista di clinica pediatrica," August, 1909, p. 652

is no relationship between the severity of the rickets and the degree of anæmia.

In the type of child suffering from "fat" rickets a fairly marked degree of anæmia is quite common clinically, associated with definite leucocytosis.

Lovett Morse * from the examination of twenty cases of uncomplicated rickets, found that the number of red blood corpuscles was either normal or nearly normal, but that the percentage of hæmoglobin was both absolutely and relatively diminished. Leucocytosis might or might not be present, and when present was due to an increase of all the varieties of white cells. Marfan † agrees with these results, but points out that in many cases where leucocytosis is present, it is due to a secondary infection, such as broncho-pneumonia, diarrhœa or syphilis, and is not an essential part of the rachitic process itself.

Findlay ‡ as the result of an examination of the blood in active and uncomplicated rickets, in thirty cases between the ages of twelve and forty-two months, came to the following conclusions, which have not yet been confirmed: (1) in active and uncomplicated rickets anæmia is not the rule, but is to be regarded as exceptional. On the contrary, in rickets the number of blood cells and the amount of hæmoglobin are notably in advance of the normal average. This may be due to a reaction against the confinement and lack of exercise which plays such an important part in the production of rickets, and may be a compensatory charge. In consequence of the deficient amount of oxygen and the defective inspiration, this polycythæmia may help the economy in limiting the evil influence of those deficiencies; (2) the red blood corpuscles in rickets vary more in size than in normal individuals of similar ages; (3) nucleated red blood corpuscles, polychromatophilia, and myelocytes are of rare occurrence; (4) leucocytes may be normal, or slightly increased, or even

* "The Blood in Rickets," by J. Lovett Morse, *Archiv. of Ped.*, Vol. XVI, 1889, p. 619.

† Marfan: *loc. cit.*, p. 346.

‡ Findlay: "The Blood in Rickets." *The Lancet*, April 24th, 1909.

slightly diminished. The mononuclears, more commonly than the polymorphs, show an absolute increase.

These results do not conform with the conclusions drawn by other observers, and are somewhat difficult to reconcile with clinical experience, where definite anæmia is frequently met with in the rachitic state.

It may be stated that while in rickets there is no distinctive variety of anæmia characteristic of the disease, there is frequently a diminution of the red blood cells and of the hæmoglobin, both relative and absolute. Slight forms of leucocytosis are fairly common and may be well marked in the incipient and active stages of the disease; if the leucocytosis is severe and prolonged, it may be due to intercurrent attacks of broncho-pneumonia, diarrhœa, syphilis, or some other infection.

Affections of the lymphatic system in rickets.

In rickets there is a marked tendency towards lymphatism. The hyperplasia which has been shown to occur in the bone marrow also affects the thymus, spleen, lymph glands, and the outlying patches of lymphoid tissue. It is owing to this state that the child assumes the fat, pale, stolid, type so characteristic of the rachitic state. The enlargement of the lymphatic glands has already been spoken of. The condition is one of true hyperplasia, and there is not the tendency to matting and massing of the glands together, such as occurs in true adenitis. Usually the glands are discrete and shotty, and can be rolled freely under the skin. They can be felt in such situations as the neck, armpit, or groin.

Fröhlich * found that in eighty per cent. of cases this enlargement was present, and that if anæmia was at all marked the enlargement was constant. The condition is a matter of some importance in the defence of the organism against infections, notably against the tubercular infection, and the better adapts the infant to its surroundings when it is compelled to live in an unwholesome environment.

* Fröhlich: "Lymphdrüsenschwellung bei Rachitis: Jahrbuch für Kinderheilkunde," XLV, 1897, p. 282.

A certain antagonism between rickets and tubercle has long been believed in by the older writers, and this is probably true of rickets in its early stages. When a failure of the defences against the tubercle bacillus does occur, the glands are most commonly affected. Even so, the failure is not usually complete, and the tuberculous infection is often limited to the glands, more often those of the neck than of other parts, and the disease is capable of being treated by several methods, or surgically, with a fair prospect of success. This is the commonest form of tubercle in children under the age of ten years. It is interesting to note that, in the child where the tuberculous diathesis, as described by Sir Wm. Jenner, is well marked, rickets rarely develops. The failure to successfully combat tubercle in these susceptible subjects may in part be due to the inability of the child to afford an effective resistance to an unhealthy environment, such as the rachitic infant is able to make.

The recurring acute catarrhal affections to which the rachitic child is liable, tend to lead to a secondary enlargement of the lymphatic glands; but it is important to remember that before the development of these infections the glands undergo a primary enlargement or hyperplasia. The lymphatic glands may be enlarged in two ways, viz. : (1) from hyperplasia as part of the rachitic process itself; (2) as a result of secondary infections, especially of the mucous membranes, to which children suffering from this disease are peculiarly liable.

The spleen in rickets.

From the time of Glisson this organ has been accurately described by all observers as somewhat enlarged. The increase in size is part of the general lymphatic hyperplasia which occurs in rickets. At first, in both the lymph glands and in the spleen, there is an increase of the cellular elements which form the parenchyma or true glandular substance. Later there is a tendency to increase of the capsule and trabecular connective tissue which surrounds the pulp. These changes are comparable to those occurring

in the bone marrow, where it has been shown there is first of all an increase of the marrow cells, while later the marrow tends to become firmer and more fibrous, owing to an increase of the connective tissue element.

In the later stages the spleen presents the usual appearance of chronic induration. On section it is firmer than natural, the capsule and the trabeculæ which extend from it being somewhat thickened. The Malpighian bodies are often enlarged but may be more difficult to distinguish from the surrounding firm tissue than in the normal spleen. Only a little pale blood can be squeezed from the cut surface, the walls of the blood vessels being frequently thickened and their lumen narrowed. It is not usual, however, in uncomplicated rickets to find the spleen notably enlarged. Fairly commonly it can be palpated just below the margin of the ribs, owing to the enlargement and induration which occurs, together with the deformation of the chest which tends to thrust the abdominal organs downwards, and to render them more easily palpable. When notably enlarged, and especially if this is associated with marked anæmia, congenital syphilis is almost always present.

The thymus in rickets.

The thymus is a lymphoid structure, which is usually notably affected in rickets. Indeed, enlargement of this structure, with definite delay in its normal involution, is so commonly seen that it must be considered an essential part of the rachitic process.

Glisson himself observed, as the result of many autopsies, that while in young children the thymus was a larger structure than in the adult, in rickets the gland was distinctly larger than in normal children. Its enlargement is important, in view of the fact that it forms part of the affection of the ductless glands, which probably in rickets plays an important part in the production of the disease.

The liver in rickets.

In the embryonic stage and up to the time of birth, nucleated red blood corpuscles are formed in the liver as well

as in the lymphatic glands, spleen, and thymus, and in rickets a slight increase in the size of the liver is fairly commonly observed. As a result of the constriction of the chest wall, the liver is thrust downwards, and is rendered more easily palpable. The organ is seldom much enlarged, but its edges are harder and sharper than in health. It is somewhat dark, hard, and elastic to the touch, but on section it is pale and contains but little blood. The fibroid tissue throughout the liver is somewhat increased. Within the acini the cells are more closely packed than in health and the cells are not rich in oil globules.*

Enlargement of the tonsils and adenoid vegetations in rickets.

In no part is the hyperplasia which occurs in the lymphatic system more marked or of greater importance than in the enlargement of the tonsils and the production of adenoid vegetations. It has been shown that out of 1,000 children in the East end of London, 800 showed definite signs of rickets. Of these 800 rachitic children, twenty-one per cent. suffered either from enlargement of the tonsils, or from adenoid vegetations, or, most commonly, from both.† The chief interest attaches to the adenoid vegetations, though their evil influence is markedly increased by the presence of large tonsils.

Normally, the posterior wall of the naso-pharynx is thickened, and is thrown into a number of folds which run chiefly in a vertical direction. In this thickened and rugose mucosa large masses of lymphoid tissue are present in the young child in health. These lymphoid masses, together constituting what is called the pharyngeal tonsil, stretch across the back of the pharynx between the orifices of the Eustachian tubes, extending into the lateral recess or fossa of Rosenmüller on each side. When hypertrophied these masses are exceedingly apt to block up the Eustachian

* "The Wasting Diseases of Children," by Eustace Smith, London, 1878, p. 146.

† "Defective Housing and the Growth of Children," by J. Lawson Dick, London, 1919, pp. 28, 29.

orifices and even the posterior nares. Catarrhal and infective conditions are very likely to pass along the Eustachian tubes, which not only contain numerous mucous glands on the inner surface of the cartilaginous portion of the tube, but which also, in the young child, contain a considerable amount of lymphoid tissue situated near their pharyngeal ends. When it is considered that, in the adult, the transverse diameter between the Eustachian cushions only measures three-fifths of an inch, and the antero-posterior diameter from the lower part of the posterior edge of the nasal septum to the posterior wall of the pharynx the same, it can readily be understood that the smaller space in the young child will be easily blocked by lymphoid overgrowth and the catarrhal conditions likely to ensue.

Now, while it is true that adenoids may arise apart from rickets, as the result of acute infections such as measles, scarlatina, and diphtheria, the great majority of cases originates in the rachitic state. In other words, adenoid vegetations, as is the case with all lymphoid overgrowths, form part of the ordinary rachitic process apart from infections. Nay more, it has been shown that in the debilitated infant, mouth-breathing is likely to develop from dropping of the lower jaw through muscular relaxation and the inability to maintain the muscular effort required to sustain nasal breathing. In such a child a negative pressure is likely to be produced in the naso-pharynx, which increases the tendency to congestion of the mucous surface and to the retention of secretions. These conditions naturally lead to further increase of the lymphoid tissue.

As has already been shown, the bones of the face are soft as the result of rickets, and the lateral pressure of the soft parts of the face tends to approximate the alveolar margins still further; there is no column of air passing backwards and forwards through the nose during respiration which would tend to depress the floor of the nose, and with it the hard palate, and at the same time, to separate the lateral walls of the nose from the septum. The result is the nose remains thin and soft, the palate is high and arched,

and the septum tends to become buckled on account of the want of space for its proper expansion.

As a result of continued mouth breathing many disabilities are likely to arise, notably : (1) frequently recurring colds and bronchial attacks ; (2) certain chest deformities which have already been dealt with ; (3) imperfect aeration of the blood associated with anæmia and generally impaired health ; (4) defective growth ; (5) deafness and affections of the ear.

Adenoid vegetations may require attention at any period from early infancy onwards, though usually they only reach a condition demanding operation after the fourth or fifth year.

In infancy snuffling, which is usually due to syphilis, may be caused by adenoids. Difficulty in suckling, owing to the infant being unable to maintain continuous nasal respiration, is met with and laryngeal stridor is common. Snoring is not a usual symptom of adenoids at this early age. When the adenoid state is present in older children the other signs of rickets are present. The teeth of the second dentition are overcrowded and irregular, and the bridge of the nose is often widened, owing to congestion of the soft parts, while the *alæ nasi* are collapsed. The child sleeps with the mouth open, and granulations may appear on the posterior wall of the pharynx, continuing below the soft palate. This may be accompanied by enlargement of the lymphatic glands along the posterior border of the sterno-mastoid. Deafness is apt to supervene, and the child is backward mentally and physically. In the adult, chronic post-nasal catarrh, deafness, and muffling of the voice point to a diagnosis of adenoids.

Aprosexia and rickets.

Deafness dependent on the rachitic state may be due to three causes, viz. : (1) a blocking up of the pharyngeal end of the Eustachian tube by an overgrowth of the pharyngeal tonsil ; (2) a chronic catarrh extending by continuity from the pharyngeal mucosa to the middle ear—chronic catarrhal

otitis media. One of the first signs that the tubes are becoming infected in this way is an indrawing of the membrana tympani ; (3) an actual infection of the middle ear by a process of extension ending in suppurative otitis media and perforation of the drum.

Infection of the middle ear is usually considered to arise as the result of acute zymotic diseases, notably scarlatina and measles. In many cases, however, no such direct connection can be made out.

The relationship of these diseases to the rachitic state is of interest.

Scarlet fever is a disease which has a distribution not unlike that of rickets. It is most common in temperate and humid climates, especially in northern and western Europe and in North America, but has failed to establish itself in Africa or in any part of Asia except Asia Minor.* It is more prevalent in urban than in rural districts, and in mining districts and manufacturing towns it attains its maximum in frequency and intensity. Children under one are comparatively rarely attacked, but the incidence rapidly increases and reaches its maximum in the fifth year of life. Thus the disease occurs chiefly in those areas where rickets is most prevalent, and in the production of the secondary infection of the ear there can be but little doubt that rickets, by producing overgrowth of lymphoid tissue and catarrhal conditions of the mucosa of the naso-pharynx, strongly predisposes to the extension of the disease to the middle ear. Many children escape scarlet fever, while but few seem to escape measles. If the relative frequency of the two diseases be considered, the probability is that scarlet fever tends to yield a higher percentage of cases of acute suppurative otitis media than any of the other acute infectious diseases. This is due to two causes : (1) the very acute nature of the throat infection ; (2) the very common association of the disease with rickets and pre-existing morbid states of the naso-pharynx.

* " Hygiene and Public Health," by B. Arthur Whitelegge, London, 1890, p. 275.

Measles, unlike scarlet fever, seems to be but little dependent either on climate or locality, and no race is exempt from its invasion. As already noted, many children of school age escape scarlet fever, while comparatively few escape measles.

It is exceedingly common in crowded populations, but it is also very common and produces a high mortality even in such situations as the high uplands of the Karroo, in South Africa, where the population is sparse and the climate is ideal. In South Africa, among native children, both Kaffir and Hottentot, epidemics of measles are much more destructive of life than they are in England.

Measles, from its tendency to attack the upper respiratory tract, is very likely to cause a spreading infection along the Eustachian tube, affecting the middle ear. Rickets undoubtedly frequently prepares the soil for this invasion. I have seen repeated severe epidemics of measles affecting native children in the high uplands of South Africa. The mortality from broncho-pneumonia is very large, but complications such as catarrhal suppurative otitis media in the children who recover are quite infrequent. At home the death rate is less high, but the proportion of cases of infection of the middle ear amongst those who survive is very high. Whooping cough is a common concomitant of measles, but tends to be more prevalent and more severe in Europe and in temperate climates generally than in hot countries. Both measles and whooping cough, unlike scarlet fever, are common in the young infant, and when combined form the most formidable depressing agent that can attack the young child. Rickets is a most serious complication, and if these two diseases attack a rachitic child during the first year of life the chances of recovery are exceedingly small.

Whether associated with acute zymotic diseases or no, chronic suppurative otitis media and chronic catarrhal non-suppurative otitis media are exceedingly common conditions affecting the general population. So common are they that but little heed is paid to them in their initial stages, and the

great difficulty in treating these cases is to persuade the mother of the child, and later, the patient himself, that these conditions are sufficiently serious to necessitate prolonged and careful attention.

At the present time there are 34,000 pensioners discharged from the army and navy with ear disabilities which are held to be due to, or aggravated by, the conditions of military service, and which are therefore pensionable. This large number by no means represents the amount of aural disease which existed in the army, but simply includes those men from Great Britain and Ireland who were discharged from the army as permanently unfit for further service on account of deafness, or who claimed, at a date subsequent to discharge, that they were suffering from an aural disability due to service. The very great majority suffer from catarrhal suppurative or catarrhal non-suppurative otitis media.

From a large experience of those men, I have little hesitation in saying that by far the greater number have suffered from these conditions from very early years. Large numbers exhibit signs which can be definitely attributed to rickets in infancy. This is seen in the condition of the jaws and teeth. Thickening and consolidation of the bones of the cranial vault, the permanent result of the reconstructive process which has taken place at an early date, is quite common. Deflection of the septum is the rule rather than the exception. It has previously been noted that, contrary to what is generally supposed, the osseous changes in rickets, when at all well marked, are remarkably constant, and are quite commonly seen in men of thirty or forty years of age. In the majority of cases the pathological state of the ears points to an old standing disease which has continued from early childhood. Scarlet fever, or measles, or influenza, may have been the actual exciting cause of an acute suppurative condition in many, but the essence of the condition was the development of adenoids and mouth breathing, and unhealthy conditions of the naso-pharynx following the rachitic state in childhood. The infection took place on a prepared soil.

Large numbers of these are men of poor physique and of a low grade of intelligence, and they constitute a difficult problem from the labour point of view. These men look degenerate, but they are merely the product of unhealthy environment operating from birth onwards.

It is an observation that has frequently been made, that, with the onset of deafness, children become duller mentally, and retrograde in their class work to an extent out of all proportion to the amount of their disability. Such cases are well known to the teacher in the ordinary primary schools.

In 1887, Prof. Guye,* of Amsterdam, drew attention to this class of patient and revived the use of the term aprosexia, a word borrowed from the Greek lexicographer Hesychius, of the fourth century, meaning heedlessness.

Aprosexia embraces the class of child which suffers from adenoids and imperfect nasal development associated with some chronic inflammatory condition affecting the ears, tending to produce deafness. These children are notably dull and their faculties of attention and observation are markedly defective. They are the despair of their teacher—they have no power of concentration, and they make no progress even with the most careful handling.

This condition is peculiarly a sequel of rickets. In these cases operative treatment of the adenoid vegetations often produces most favourable results. A child from being dull and listless and apathetic, with a pale and pasty complexion, may become alert and active, with a better colour and improved general health, in the space of a few days. Such favourable results are a matter of common experience after this comparatively simple operation, and the improvement is maintained and progressive. Prof. Guye held that this improvement was due to the relief of a condition of congestion of the intra-cranial circulation. He maintained, what is anatomically correct, that the intra-cranial veins have communications with the veins of the frontal, ethmoidal,

* "On Aprosexia," and etc. *British Medical Journal*, 1889, Vol. II, p. 709. "Ueber Aprosexia." *Deutsche med. Wochenschrift*, Leipz. u. Berl., 1887, xiii.

and sphenoidal sinuses, and through these with the vessels of the nose and naso-pharynx.

Retzius showed that intra-cranial lymphatics are in connection with lymphatics lying in the cranial nerve sheaths, and that these lymphatics, passing from the frontal region of the brain through the criciform plate of the ethmoid in the sheaths of the branches of the olfactory nerves, are in direct communication with the nasal and naso-pharyngeal lymphatics, which in their turn pass to the lymphoid tissue and glands of the naso-pharynx. Thence the efferent lymphatics proceed to the lymphatic plexus on the pterygoid muscles and from thence to the anterior cervical glands.* Such an anatomical continuity is of great interest and importance as a possible line of infection, but it is unlikely that it is commonly so. If it were a common path of infection it might reasonably be expected that every now and then accidents would occur after these operations, which are often performed under conditions far from favourable. As a matter of practice accidents are exceedingly rare, and a more real source of danger arises from the fact that most of these cases are associated with lymphatism; actual status lymphaticus with the tendency to sudden death under an anæsthetic is a danger to be guarded against in these cases.

The establishment of a free passage way for the current of air through the nose, and the better aeration of the blood, with the relief of local congestion and improved sleep, seem quite adequate to explain the beneficial results which follow the operation.

Shaw examined 693 school children for signs of aprosexia. One hundred and nine of these children were pointed out as below the average mentally, and in twenty-five of these evidence of adenoids was definitely present. That is, 3·5 per cent. of all the children attending the school suffered from this condition.

This syndrome is so definite, and the promise of benefit from active treatment at an early stage is so great, that the

* "Aprosexia in Children," by Ernest A. Shaw. *The Practitioner*, Vol. XLV, July, 1890.

term aprosexia might, with advantage, be more freely used than it is, and the condition recognised as a true entity.

If left untreated these children are likely to result in failure in later adult life, and to drift into the class who swell the casual labour market or who belong to the unemployed.

PART II

THE NATURAL HISTORY OF RICKETS
THE ÆTIOLOGY OF THE DISEASE AND ITS
TREATMENT

CHAPTER XIX

THE LITERATURE OF RICKETS

Glisson and His Times

THE history of rickets properly begins with the publication of Glisson's book "*De Rachitide*" in 1650. It was published in Latin under the title "*De Rachitide sive Morbo Puerili qui vulgo The Rickets dicitur, Tractatus.*"* In 1651 it was republished, translated into English by Phil. Armin.† The work impressed itself at once on the medical thought of the time not only in England, but throughout Europe, and several editions were published in this country and abroad between 1650 and 1682.

Francis Glisson was born in 1597 at Rampisham, in Dorsetshire, and he died in London in 1677. He entered Caius College, Cambridge, in 1617, graduating B.A. in 1621 and M.A. in 1624, and was elected a Fellow of the Royal College of Physicians, London, in 1635. On October 25th, 1627, he was incorporated M.A. Oxford. In 1636 he was appointed Regius Professor of Physic at Cambridge, an office which he held till his death. At the Royal College of Physicians, London, Glisson lectured on anatomy, which at that time included pathological and comparative anatomy

* "*De Rachitide sive Morbo Puerili qui vulgo The Rickets dicitur, Tractatus; Opera primo ac potissimum Francisci Glissonii Doctoris, et publici Professoris Medicinæ in alma Cantabrigiæ Academia et Socii Collegii Medicorum Londinensum, conscriptus: Adscitis in operis societatem Georgio Bate et Ahasuero Regemortero Medicinæ quoque Doctoribus, et pariter Sociis Collegii Medicorum, Londinensum, Little Britain, 1650.*"

† "A Treatise of the Rickets, being a Disease common to Children, wherein (among many other things) is shewed (1) The Essence; (2) The Causes; (3) The Signs; (4) The Remedies of the Disease. Published in Latin by Francis Glisson, George Bate and Ahasuerus Regemorter, Doctors in Physick and Fellows of the Colledg of Physitians at London. Translated into English by Phil. Armin, London. Printed by Peter Cole at the sign of the Printing Press in Cornhill, near the Royal Exchange, 1651."

besides normal anatomy,* and he published a book on the anatomy of the liver, "*Anatomia Hepatis*," in 1654, in which the capsule, or fibrous sheath, of the liver is so accurately and fully described that the name of Glisson's capsule, familiar to every student of medicine, is now given to it.

In the Sloane MSS. at the British Museum are preserved several interesting relics of Glisson. That he was a prolific writer is shown by ten large volumes containing the manuscript of his lectures at the Royal College of Physicians alone. There are several letters from patients requesting advice and thanking him for previous help. One dated June 26th, 1671, written from Thorpe, thanks him for his care of a rickety child. "There hath since been but little appearance of them [the rickets] more than by a greater weakness in him than in other children of his own age and a crookedness of his legs: He is now about 4 years and 4 months, and hath been affected with a quartan ague ever since the last day of August last." In a quaint, very elaborate and laborious journal of the weather for the years 1675-1676 to 1678-1679 kept by J. Conyers there is a note of the death of Glisson: "Now in September, 1677, my very good friend and unckle (Dr. Francis Glisson, aged about 83) about September 4th began to be very sick, . . . until September 19th, when at night he was taken up dead in his chamber when he was going into bedd by reason of some vertigo." †

Glisson's chief claim to fame is his great work on rickets. This work places him in the front rank of illustrious men in the history of medicine. He was a product of an age of great advance in scientific thought. Harvey published his discovery of the circulation of the blood in 1628, when Glisson was thirty-one years of age. In France the mechanical philosophy of Descartes and the progress of physics profoundly affected medicine throughout Europe, and led to the application of mechanical ideas to physiological processes.

* Article by Sir Norman Moore on Glisson, "*Dictionary of National Biography*."

† "*Register of the Weather from 1675-6 to 1678-9 inclusive*," by J. Conyers, Sloane MSS. 816, fo. 219.

Thus the movements of bones and muscles were referred to the theory of levers, digestion was held to be essentially a process of trituration, and metabolism and secretion were stated to be dependent upon the tension of the bloodvessels. Harvey's discovery, combined with these Cartesian principles, stirred many active minds to work out a new system of scientific medicine. Glisson was twenty-nine years of age when Bacon died, and he completed "*Novum Organon*," which is specifically mentioned in "*De Rachitide*," was published when he was twenty-three.

Two other great names are associated with that of Glisson. Newton was born when Glisson was forty-five years old, and must in later years have known Glisson well both at Cambridge and in London. In 1669 Newton was appointed Lucasian Professor of Mathematics at Cambridge, while Glisson still held his chair. Glisson was one of the original Fellows of the Royal Society, and Newton was elected a Fellow in 1672. Sir Thomas Browne must also have known Glisson, probably intimately. Browne settled in Norwich in 1637, and rapidly acquired a reputation for skill as a medical practitioner. At this time Glisson still resided chiefly at Cambridge, but in 1640 he moved to Colchester, and soon obtained much practice there. Both were men widely known for their professional skill, and the advice of both was much sought by the wealthier families over a wide area. It may well be that Glisson, the senior of the two both in years and in the practice of his profession, consulted with Browne over difficult cases. For eleven years (1637-1648) they practised in neighbouring counties, Browne being at Norwich and Glisson part of the time at Cambridge and the rest of the period at Colchester. Both Browne and Glisson were Royalist in their sympathy during the Civil War, and Glisson not only sympathised with, but took an active part on, the Royalist side. He was in Colchester during the two months' siege, and on August 21st, 1648, six days before the town capitulated owing to starvation, Glisson was sent by the Royalists to Lord Fairfax to ask for better terms, but failed to obtain any concession. His

activity on the Royalist side, however, does not seem to have unduly prejudiced his position with Cromwell. In the British Museum is preserved the original order of the Protector and Council, dated April 7th, 1654, to the Receiver-General of Revenue, ordering the payment of the salary of his professorship to 1654. Glisson was appointed a censor of the College of Physicians 1656, and was President of the College during the years 1667, 1668, 1669. In 1664 Browne was elected a Fellow of the College of Physicians, and he frequently contributed papers to the Royal Society, of which, however, probably much to his regret, he never became a Fellow.

After the siege of Colchester the town was much impoverished, and Glisson went to London and settled in the parish of St. Bride, where he remained till his death. There is a certain similarity in the writings of Browne and those of Glisson. Both are dignified, and show a love of scholastic forms, which was largely due to the fact that both wrote in Latin. Several passages in "A Letter to a Friend," perhaps the most charming of all Browne's writings, show that he was familiar with "De Rachitide," though he does not mention Glisson by name. But while Browne was quaint and discursive and cast his net widely over all subjects of human interest, Glisson, as became a follower of Bacon's inductive philosophy, was incisive and held himself to his subject, even in the long disquisition on the philosophical side of medicine which occupies so much of his work.

It is worthy of note that, while Glisson adopted the experimental method expounded by Bacon, he made no attempt to separate himself from the humoral pathology of Galen which had dominated medical thought throughout Europe for many centuries. Galen considered that all diseases had their origin in the fluids of the body, and that the normal condition of the body depended upon a proper mixture of four *elements*: heat, cold, wetness and dryness. From faulty mixtures or proportions of these so-called elements distempers arose which, while not diseases in themselves, were yet the causes of all diseases. Into the theories of disease as elaborated at

great length by Glisson it will not be necessary to enter. The subject is treated in a philosophical manner with great dignity of diction, and is chiefly of interest from the historical point of view, as giving the prevailing ideas of the time on the origin of disease. In language unfamiliar to present-day readers Glisson holds : (1) that rickets is a cold distemper ; (2) that it is moist ; (3) that it consisteth in penury or paucity of the spirits ; (4) that it consisteth in the stupefaction of the spirits. The minuteness with which the origin of all diseased conditions could be argued out on these lines appealed to the philosophic side of the most advanced minds, and Glisson warmly attacks the problem on the old lines.

It was not till the seventeenth and eighteenth centuries that this system of humoral pathology was slowly undermined. Cullen, who was appointed Professor of Medicine in Glasgow in 1751, and who removed to the chair at Edinburgh in 1756, delivered his famous lectures there and built up the system of pathology known as *solidism*. He denied that the liquids of the body had anything to do with disease, and held that all diseases arose in the solids of the body. These solids were either simple, their functions being the same in animate as in many inanimate bodies, or vital, whose properties appeared only in living bodies. Simple solids, he taught, having fewer functions, had fewer diseases to which they were liable, and these were easily classified. But according to Cullen the real difficulty was with the vital solids, because on their peculiarities the whole condition of the nervous system depended, and nearly all diseases were due to them. Cullen therefore made the nervous system the basis of his pathology. As Buckle * points out, Cullen's system erred on the other side, but it was a mistake of a salutary kind, for it led to a gradual cessation of the constant and indiscriminate venesection which had prevailed whilst the blood and the fluids of the body were believed to be the seat of disease. Glisson believed that rickets was a diseased condition of the blood, and chiefly of the liquid parts of the blood, though the solids also contributed.

* " Civilisation in England," Buckle, London, 1904, Vol. III., p. 415.

The ease with which Galen's philosophy lent itself to explain every problem connected with disease, and the appearance of finality with which it could be applied to any theory, hampered the progress of medicine for many centuries, and Glisson, with his love of logic and philosophical discussion, never threw off its fetters. Theory is requisite to connect ascertained facts and to guide us in their application. It is useful to point out the way to future workers, but all theories must be elastic and adaptable so as to conform to each addition to our knowledge, and must not be held in themselves to be final and definite. It is in the application of the inductive method of Bacon to the study of this new disease that Glisson shows his greatness. When he argues from his own observations his work is marvellously clear and brilliant.

"De Rachitide" is the first monograph of importance on a disease in this country. John Caius, the learned co-founder of Gonville and Caius College, Cambridge, it is true, published a book in 1552 on the "sweating sickness,"* but this is a small volume of thirty-nine pages written for popular instruction, and lays no claim to important original research. The academical physicians of the Tudor period hardly ever wrote. The men who wrote on medicine were men like Sir Thomas Elyot (1490-1546), or irregular practitioners anxious to advertise themselves, or booksellers' hacks. Up to Glisson's time medical works were not addressed, as they now are, to the medical profession, but were meant to be read by all who were interested in polite learning. This custom lasted long after Glisson's time. Naturally writing in Latin limited the audience in certain directions, but it widened the area of the appeal, in that the work could be read all over Europe in learned circles. Not only did medical men write for the information of the general public, but it was not uncommon for amateurs interested in experimental science to write on philosophical and medical subjects. Robert

* John Caius, 1510-1573 (Anglicè Kees, Keys, etc.), "A Boke or Counseill against the Disease commonly called the Sweate, or Sweating Sicknesse," London, 1552, in Latin, "De Ephemera Britannica," Louvain, 1556, reprinted London, 1721.

Boyle (1627–1691), the great natural philosopher and chemist, spent his life in the experimental study of various branches of natural science, and was one of the founders and afterwards President of the Royal Society. He also, however, meditated and wrote on theological subjects, and he learned Hebrew and Greek so that he might read the Bible in the original. So much was he devoted to the study of theology that Lord Clarendon strongly urged him to enter the Church.

Stephen Hales (1677–1761), the great physiologist, chemist and inventor, graduated M.A. at Cambridge in 1703 and proceeded to take Holy Orders. In 1708–1709 he was presented to the perpetual curacy of Teddington, in Middlesex, where he remained all his life, notwithstanding that he was subsequently appointed rector of Porlock, in Somerset, and later of Faringdon, in Hampshire. In 1717 Hales was elected a Fellow of the Royal Society, and in 1727 was published his great work on “Vegetable Staticks,” and in 1733 his work on “Hæmo-Staticks,” where he dealt with his experimental results on blood pressure.

Glisson’s book was a new departure in the history of medical literature, and, like many other fresh ventures, the work produced belongs to the first rank and has never since been surpassed or superseded. Once and for all Glisson defined rickets as a separate entity, and so successful was he in delimiting the disease that, so far as the naked eye anatomy goes, not a great deal has been added to our knowledge of the condition up to the present day.

The name of rickets was in common use throughout England in 1650, when Glisson published his work. The general belief of the time was that it was comparatively a new disease. It is first described as a cause of death in the table of casualties in the Bills of Mortality for London in the year 1634.* The word “rickets” is probably derived from the Middle English word *wrikken*, to twist. It is connected with the word “rick,” as in “ricked ankle” and “ricked back,”

* “Reflections in the Weekly Bills of Mortality from the Cities of London and Westminster and the Places adjacent,” Captain John Graunt, London, 1665.

which is a variant spelling of "wrick." Cognate words are "wring," "wry" and "wrong." Glisson in his book suggested the word "rachitis," from the Greek *ραχίς*, the spine, as being a suitable scientific name, which had not only the advantage of resembling the popular name for the disease in sound, but also denoted the part which was first affected.

The origin of "De Rachitide" is interesting. It represented work extending over a period of five years. Glisson communicated his observations to other Fellows of the Royal College of Physicians, and apparently at informal meetings seven Fellows added further notes and observations. Three of these Fellows were appointed to prepare a treatise on the subject, but, as the work progressed, it became evident that Glisson's observations were so voluminous, and so complete, that the other two courteously withdrew, and asked him to undertake the whole work lest they should destroy its unity and harmony. Glisson undertook the task, but, with equal courtesy, he insisted that the other physicians should lend him the aid of their suggestions and criticisms, and the names of George Bate and Ahasuerus Regemorter are associated on the title-page with his name as joint authors. Thus the work was freely discussed in medical circles in London for some years before it was published. Not only was the subject talked of amongst physicians, but it was a topic of interest in lay circles in London and elsewhere.

It is to be noted that two editions of the English translation were published in 1651; at least there are two copies, each precisely the same in the body of the book, but in one copy there is an addition on the title-page which reads as follows: "Enlarged, corrected and very much amended throughout the whole book by Nich. Culpeper, Gent., Student in Physick and Astrology, living in Spittlefields, neer London." In both copies it is stated on the title-page that they are "Printed by Peter Cole in Leaden-Hall, and are to be sold at his shop at the sign of the Printing-press in Cornhil, neer the Royal Exchange, 1651." Nicholas Culpeper (1616-1654) was an active figure in London during his short life.

He was on the Parliamentary side in the Civil War, and was said to have fought and to have been seriously wounded in the chest. Culpeper was a herbalist who combined astrology with the practice of medicine in Red Lion Street, Spital-fields, and was at variance with the College of Physicians, to whom he had given much offence. He first roused the indignation of the College by publishing an unauthorised translation of the College of Physicians' Pharmacopœia.*

He was closely associated with Peter Cole, the printer, and evidently acted as his medical publisher. But Culpeper was himself a prolific writer on medical subjects, and his books sold remarkably well. In September, 1653, he again trespassed on the monopoly claimed by the recognised medical writers by publishing, with Peter Cole, a book entitled "The English Physician."† This book had an enormous sale.

Culpeper, notwithstanding the statement "enlarged, corrected and very much amended" on the title-page of the English translation of "De Rachitide," does not seem to have interfered with the matter of the work, though he may have amended the translation, for he was an excellent Latin and Greek scholar. There could be no sympathy between Glisson and Culpeper, and the part the latter played as medical agent for Peter Cole was probably wholly unauthorised, and the addition of his name to the title-page strongly objected to. Doubtless it would greatly aid the sale of the work, but there is evidence that his efforts were not appreciated by the authors of "De Rachitide," for two years later he rails against the whole College of Physicians, and against Glisson in particular, for some statements in the work which he himself had apparently failed to amend.‡

As already stated, the history of rickets begins with the publication of Glisson's book, but it was not actually the

* "A Physical Directory or Translation of the London Dispensatory," published for Peter Cole, London, 1649.

† "The English Physician, enlarged, with 369 medicines made of English Herbs that were not in any impression until this. The Epistle will inform you how to know this impression from any other."

‡ Galen's "Art of Physick, by Nich. Culpeper, Gent., Modern, etc.," printed by Peter Cole, London, 1652.

first book published on the subject. Daniel Whistler—1619 to 1684—was born at Walthamstow, in Essex, and entered Merton College, Oxford, in 1639, graduating B.A. in 1642 and M.A. in 1644. He took his degree of M.D. at Leyden in 1645, and on October 18th, 1645, he read as his inaugural address a short treatise on rickets. This was published in Leyden in the same year, that is five years before the publication of Glisson's work, under the title "*Disputatio Medica inauguralis de morbo puerili Anglorum quem patrio idiomate indigenæ vocant the rickets.*" It was republished in London in 1684. Whistler, a notable man in his day, was elected President of the Royal College of Physicians in 1683, and is mentioned in the diaries of both Samuel Pepys and John Evelyn. But Glisson owed nothing to his work. Sir Norman Moore points out * that Whistler's book does not bear the impress of original work; he speaks of rickets as having been discussed by learned men, and he alludes several times to a very learned man, probably meaning Glisson, but nowhere does he mention the names of his authorities. As Sir Norman Moore somewhat caustically remarks, while Whistler does not claim originality for his work on rickets, he does claim to be the originator of the name "*pædosplanchnosteocaces*" for this disease, and he was the sole user as well as the sole inventor of the word.

It has been suggested that Whistler pirated his information and made use of it without acknowledgment. In 1645 Whistler, at the age of twenty-six, had just graduated, while Glisson was forty-eight years of age, well established as one of the most learned men of his time, and had already been Regius Professor of Physic at Cambridge for eleven years. Probably Whistler was quite open about the fact of having used Glisson's work for his inaugural thesis; indeed, it would have been impossible for him to conceal it, for Glisson at this time was actively engaged in making the research and observations necessary for his great work, and was already holding informal and open meetings with other

* "*The History of the First Treatise in Rickets,*" St. Bartholomew's Hospital Reports, Vol. XX., 1884.

Fellows of the College of Physicians to elaborate the subject. Glisson would think nothing of a keen young pupil having made use of his work in a comparatively unimportant graduation thesis published in Leyden, especially when the subtle flattery of "*vir consummatissimus*" was used in referring to him, even if it were only by implication and not by name. Jonathan Goddard, M.D., F.R.S., is one of the seven names mentioned at the end of Glisson's preface as having collaborated with him in his work. It is interesting to note that Pepys in his diary makes the following entry on February 15th, 1664 :—

" After this being done, they to the Crown Tavern behind the Change, and there my Lord (Brouncker) and most of the company to a club supper : Sir P. Neale, Sir R. Murray, Dr. Clerke, Dr. Whistler, Dr. Goddard, and others, of the most eminent worth."

There was apparently no animosity felt by Goddard against Whistler on account of his publication, even though the only observations of value it contained were borrowed from Glisson and his collaborators. If further evidence that no slight was meant or felt is required, it might be found in a list lying in the Sloane MSS. in the British Museum headed " Subscription towards building of a Colledge, 28th April, 1669 : those who have subscribed and paid." Dr. Glisson, President, heads the list with £100 ; next to him comes the ever-generous Dr. Hamey with £100, followed by Dr. Goddard £40, Dr. Whistler £50, Dr. Wharton £40, and several others.

A second and more notable publication than Whistler's appeared in 1649, one year before Glisson produced his work. Arnold de Boot, also known as Arnold Boate or, in the latinised form, as Arnoldus Bootius, was a Frisian who practised in Ireland for some time. In 1649 he published a treatise, "*De Affectibus Omissis*," one chapter of which deals with the subject of rickets.* He states that, while up to recent years rickets was exceedingly rare,

* "*Observationis Medicæ de Affectibus Omissis, Authoræ Arnoldo Bootio, Lond., 1649. Caput duodecim, De Tabe Pectoræ.*"

the disease is now (referring to the date of his publication) common both in England and Ireland, and accounts for several thousands of deaths amongst infants each year. He himself, he affirms, has had frequent opportunities of making autopsies on these cases. With great accuracy he describes the signs of the disease, noting carefully and in detail the alteration in the formation of the chest, the enlargement of the wrists and ankles, the tendency to spinal curvature, and the relative enlargement of the skull. He is of opinion that the disease may be acquired at the time of conception, and may be due to the defective constitution of one or other of the parents, or that it may arise during the period of gestation owing to a faulty regimen on the part of the mother, or that it may appear soon after birth from the persistence of these errors affecting the child through the breast milk. It is very probable that he was acquainted with Whistler's short treatise, and he may have obtained much of his knowledge from Glisson himself. But his work gives the impression of information obtained at first hand, and he seems to have had a considerable experience of the disease in his own practice. He makes the interesting statement "Not only does this disease exist in England and Ireland, but in other regions it is probably also present, and so far as Gaul is concerned, to my knowledge, it most certainly exists. Indeed, in the space of three and a half years since these things were written I have seen various children here at Paris labouring with the disease, and by these methods familiar to me and by the principles indicated I have happily been able to effect a cure." *

As early as 1609 Guillemeau, a French surgeon, published an excellent treatise on the nursing of children,† and though he, of course, does not speak of rickets by name or define

* "Morbum istum non in Anglia duntaxat et Hibernia, sed et in Aliis quoque Regionibus grassari verisimile est, et de Gallia quidem mihi certissimo constat. Quippe illo trium annorum et dimidi spatio, quod effluxit, ex quo ista scripserim, diversos hic parisiis infantes vidi eo laborantes eosque methodo mihi usitata atque isto capite indicata fœliciter persanavi" (*loc. cit.*).

† "De la nourriture et gouvernement des enfans dès le commencement de leur naissance," etc., Paris, 1609, 8.

the condition, it is difficult to believe that he is not dealing with this disease. "We must have an eye," he says, "that the nurse or she that mothers him and dresseth him doe not make him worse, and of a well-fashioned child, in all the parts of his body, do not make him deformed or misshapen, and so spoile him. For in swathing the child most commonly they bind him and crush him so hard that they make him grow crooked. . . . This crushing makes his breast and the ribs which are fastened to the back bone to stand out, so that they are bended and draw the vertebræ to them, which makes the back bone to bend and give either inwardly or outwardly or else on the one side, and that causeth the child to be either crump-shouldered or crooked-brested, or else to have one of his shoulders stand further out than the other. Some also bind the hips so hard that they become very small, and that hinders them from growing and waxing big. Galen has observed," he continues, "that the too straight and hard binding or crushing of the hams and legges of little children when they are swathed doth make them grow crooked-legged, and they will remaine, as the Latines call it, Vari or Valgi, growing either inward or outward with their knees." *

Of course tight binding of the limbs might easily produce bending of the bones apart from any rachitic change, but the description given by Guillemeau of the chest deformities, the spinal curvature, the prominent shoulder, and the deformities of the lower limbs, points to rickets.

To return to Glisson's work, Glisson places his anatomical observations under four headings:—

"I. *Anatomical observations, the body not yet being opened, which are outwardly visible upon the first appearance of the naked dead body:*—

1. An irregularity or disproportion of the parts; namely, the head bigger than ordinary and the face fat and in good constitution in respect of the other parts;
2. The external members and the muscles of the whole

* "Child-birth, or the Happy Deliverie of Women, to which is added a Treatise of the Disease of Infants and Young Children," written in French by James Guillemeau, translated into English, London, 1612.

- body were slender and extenuated, as if they had been wasted with an atrophy or a consumption ;
3. The whole skin, both the true and also the fleshy and fattish membrane, appeareth lank and hanging loose like a glove ;
 4. About the joints, especially in the wrists and ankles, certain swellings are conspicuous ;
 5. The articles or joints and the habits of all the external parts are less firm and rigid and more flexible than at another time they are observed to be in dead bodies ;
 6. The breast is outwardly lean and very narrow, especially under the arms, and seemeth on the sides to be, as it were, compressed ; the stern also is somewhat pointed like the keel of a ship or the breast of a hen ;
 7. The top of the ribs, to which the stern is conjoyned with gristles, are knotty, like unto the joints of the wrists and ankles ;
 8. The abdomen is lean, but inwardly in respect of the parts contained in it is somewhat sticking out, and seemeth to be swelled and extended.

II. *The abdomen being opened*

1. The liver in all that we have dissected hath exceeded in bigness, but was well coloured, and not much hardened nor contaminated by any other remarkable vice ;
2. The spleen for the most part not to be contemned ;
3. We have sometimes espied a wheyish water in the cavity of the abdomen, but, indeed, not often, nor in any great plenty ;
4. The stomach and guts are somewhat more infected with flatulent humours than sound bodies usually are ;
5. The mesentery is sometimes faultless and sometimes affected with glandulous excrescences ;
6. The kidneys, ureters, and bladder, unless there be a concomitancy of some other disease, are laudably sound. We observe in general of all the viscera contained in the abdomen that, although the parts containing them are very much extenuated and emaciated, yet are they as large and as full, if not larger and fuller, than those seen in sound bodies, as hath been said of the liver.

III. *The stern being withdrawn."*

Various morbid conditions are described, such as pleuritic adhesions, blocking of the air passages by thick humours and enlargement of the mediastinal glands, but Glisson is

careful to observe that in cases dying from this disease not all the conditions found *post mortem* can be ascribed to rickets itself, but may be due to other complicating diseases which invade the body before death. With shrewd observation he notes that the thymus is always found to be great in childhood, but is perhaps greater yet in this disease.

“IV. *The skull being opened.*”

The dura mater is described as being firmer and more adherent to the skull than normal. In some bodies between the dura and the pia mater and in the very ventricles of the brain wheyish and waterish humours have been found. Sometimes he notes the condition is complicated with hydrocephalus.

The signs of rickets he discusses at length under five headings :—

- “(I.) the diagnostical ;
- (II.) signs which belong to the disproportioned nourishment of the parts ;
- (III.) the signs which belong to the respiration ;
- (IV.) those that appertain to the vital influx ;
- (V.) certain vagabond and wandering signs.”

The beading which takes place at the junction of the bony end of the rib with the cartilage and the enlargement at the epiphyseal ends of the long bones, with the general softening and bending of the bones, are all accurately described. The teeth, he notes, come forth slowly and with trouble ; they grow loose upon every slight occasion ; sometimes they wax black, and even fall out by pieces. In their stead new ones come again, though late and with much pain. Under the diagnostical signs he gives the following excellent clinical picture of the disease :—

“The younger children who are carried about in their nurses arms when they are delighted and pleased with anything do not laugh so heartily, neither do they stir themselves with so much vigour, and shake and brandish their little joynts, as if they were desirous to leap out of their nurses hands ; also when they are angered they do not kick so fiercely, neither do they cry with so much fierceness, as those who are in health. Being grown greater, and committed to their feet, they run up and down with a wayward uncheer-

fulness; they are soon weary, and they love to play rather sitting than standing, neither when they sit do they erect their body with vigour, but they bend it sometimes forwards, sometimes backwards, and sometimes on either side, seeking some props to lean upon that may gratify their slothfulness. They are not delighted like other children with the agitation of their bodies, or any violent motion; yea, when the disease prevaleth they are averse from all motion of their limbs, crying as they are at any play that is never so little vehement, and being pleased with gentle usage and quiet rest. Their countenances are much more composed and severe than their age requireth, as if they were intent and ruminating upon some serious matter." A more accurate picture of the young child suffering from well-marked rickets could hardly be given, as they sit in their quaint cross-legged attitude, like figures of the contemplative Buddha, anxious only to remain still and to be left alone, and yet observant of what is going on around.

The relationship of syphilis, scurvy and tubercle to rickets is discussed at some length, and these diseases could hardly be more accurately delineated than in the words of Glisson: "If the French pox chance to be complicated with this disease, it is rather derived from the nurses infection, or from the parents by inheritance. For it is a disease altogether distinct from this, and hath scarce any affinity with it. The scurvy is sometimes conjoined with this affect. It is either hereditary or perhaps in so tender a constitution contracted by infection, or, lastly, it is produced from the indiscreet and erroneous regimen of the infant, and chiefly from the inclemency of the air and climate where the child is educated. For it scarce holdeth any greater commerce with this disease than with other diseases of longer continuance, wherein after the same manner the blood in time contracteth for the most part this peculiar infection, yet it must be granted that this effect doth somewhat the more dispose to the scurvy in regard of the want of motion and exercise.

"The strumatical affect doth sometimes associate this evil. But it is credible that it oweth more to other causes

proper unto it than to this precedent disease, although we deny not but this may minister some occasion of invading, in as much as it rendereth the humors more viscous and gross."

It is a remarkable fact that Glisson in his work on rickets was the first to describe another important disease in infants, viz., infantile scurvy. His very clear and explicit description of the condition was lost sight of for considerably over two hundred years, and no other writer makes any mention of it. In the latter half of the nineteenth century the material for the study of scurvy in adults was rapidly diminishing, and but little interest was taken in the disease till Sir Thomas Barlow, in 1883, described the condition which came to be variously known as acute rickets, scurvy rickets, or Barlow's disease, and the relationship between infantile scurvy and the adult form was warmly discussed. Two opinions prevailed after Barlow's description : (1) that the disease was essentially rachitic in origin with the symptoms of scurvy superimposed ; (2) that it was a true form of scurvy, differing in no way from the adult variety.

The question can now be considered as settled, and Glisson's original view has been established that infantile scurvy is a true scurvy and is entirely independent of rickets, although both conditions are not infrequently present in the same subject.

Both at home and abroad Glisson's work was widely read, and was in itself so complete that for a long time nothing very original was written about rickets. The literature is encumbered with many unimportant treatises, many of them graduation theses, published in Edinburgh, Leyden and elsewhere.

Glisson was convinced that he was dealing with a new disease. He specifically states, " This is absolutely a new disease, and never described by any of the ancient or modern writers in their practical books which are extant at this day of the diseases of infants. But this disease became first known (as near as we could gather from the relation of others after a sedulous inquiry) about thirty years since, in

the counties of Dorset and Somerset, lying in the western part of England, since which time the observation of it hath been derived unto other places, as London, Oxford, Cambridge, and almost all the southern and western parts of the kingdom; in the northern counties this affect is very rarely seen, and scarcely yet made known among the vulgar sort of people." This was the general belief of the times, supported by the evidence of such names as Mayow, Sir Thomas Browne, and later by Boerhaave.

It has been affirmed by some that the disease is co-existent with civilisation, but this is certainly too wide a generalisation. It is true that rickets is common in all the highly civilised communities in Europe, but the progress of civilisation does not necessarily involve the abandonment of the principles of healthy living. The disease is a product of industrialism, and industrialism as it exists to-day in England, and Europe, and America, is a growth of comparatively recent times. But such is the stupefying influence of familiarity, and the spirit of unwholesome and lazy tolerance which it breeds, that it is difficult at the present day to imagine the existence of a town without slums, or to think of the existence of young infant life without rickets.

Unfortunately the growth of industrialism in Europe has usually been spoken of as if it were synonymous with the advance of civilisation, and the progress of a nation has been judged by the increase in wealth and the output of its factories. That this has been to the detriment of the health and true happiness of nations has been lost sight of, and in the struggle for increased industrial prosperity, efficiency has been sacrificed with disastrous results.

The evidence is fairly conclusive that the disease is of comparatively recent origin, but Glisson's definite statement that it began in the south-west of England thirty years before he published his book—that is, in 1620—need not be taken too literally. It probably began to be prevalent in England somewhere towards the end of the sixteenth century.

That it was common in certain parts of the Continent

some time before that date seems fairly certain. Arnold de Boot, as already noted, was well acquainted with the disease on the Continent, and described it accurately and in some detail before Glisson published his work. If no other evidence were available than the works of the early masters in painting, these would, in themselves, be sufficient to establish the fact that rickets was known in Europe, on the Continent at all events, before that date. In the dawn of painting in the thirteenth and fourteenth centuries, leading up to the period of greatest achievement in the sixteenth century, the Madonna and Child are very frequently portrayed. When we study the early Flemish painters the shape of the heads of the Virgin and Child is very striking. In many the *front olympien du rachitisme* of the French is exceedingly well marked, the forehead being high and square, and often showing well-marked bossing in the region of the frontal eminences. The type is repeated so frequently that it must have been a national conformation, not an accidental choice of models which led to its being so frequently depicted.

To quote from examples in the National Gallery in London alone, in the paintings of such early masters as Boutts, Daret, Geeraert David, van der Goes, and, to a lesser extent, Memlinc, all of the fifteenth century, typical examples are numerous. In the works of the master from Delft (1520) the heads of the female figures show gross changes strongly suggestive of a rachitic deformation. The same type is seen in the paintings of the Cologne school of the fifteenth and early sixteenth centuries. It is also found in later Dutch masters of the seventeenth century, such as Nicholas Maes. Rubens, who rejoiced in lusty and vigorous life, chooses a different type of model, and his robust figures are mostly free from any such stigmata. Michael Sweertz (seventeenth century), has an interesting portrait group of a Dutch family in the National Gallery, where the heads of the children are strongly suggestive of well marked and active rickets.

In the Italian school Leonardo da Vinci (1452-1519)

and Bronzino in the sixteenth century painted heads of a much more refined type, conveying no suggestion of rickets. The same is true of the early Spanish school, and Velasquez and Murillo in the seventeenth century, and Goya in the eighteenth century, depict heads of a much more delicate order. Even in the wonderful series of court dwarfs painted by Velasquez the rachitic type is wanting. Nor would it be surprising if it were found that the disease first developed in the bleak, low-lying and marshy land of Flanders. Besides having a cold and wet climate, Flanders was then the hub of the industrial universe, and, in spite of the increase in wealth, the pernicious influences of industrial concentration were probably felt at an earlier date in that country than elsewhere.

The decay of long-established diseases and the onset of fresh maladies are common features in the world's history. In and about this time, that is during the fifteenth century, leprosy diminished greatly in Europe without any obvious cause. Though the time and place of origin of syphilis have not yet been definitely settled, there can be no doubt that there was a sudden and widespread diffusion of the disease throughout Europe at the beginning of the last decade of the fifteenth century. Rickets probably first became an important factor in England towards the close of the sixteenth century, and when described by Glisson had already spread far and wide throughout England. In Flanders and the Netherlands generally and the towns of North Germany rickets had probably existed from the fifteenth century onwards. The wide diffusion of this disease is generally associated with dense populations. Europe through the Middle Ages had been asleep, and was only now, in the fifteenth century, awaking from her lethargy and entering upon the struggle culminating in the Reformation. But this lethargic state had not involved the northern towns. The Hanseatic League, as is well known, was an association of towns in the north of Germany and the adjoining States at first for the protection of commerce at sea, which rapidly, however, acquired great political power. Under its fostering influence

enormous towns grew rapidly, and many of the worst features of industrial concentration were reproduced in the change in the manner of life of the people and the crowding together of dense masses of the population in slum areas. Houses and workshops were huddled together in irregular and winding lanes, because of the greater facilities offered for business and trade by having everything within a small compass. The vitiated air in those closely built towns, and the lack of sunshine, and of the opportunities of exercise, were especially injurious to the infant and to the young child. Wealth was enormously increased, but the spread of luxury and the better distribution of foodstuffs could not stay these evils, which sapped the life of the nation at its very source in that they bore most heavily on the infant.

In these great towns in Northern Europe I think it probable that rickets developed as a national disease for the first time in the history of the world.

Bruges as far back as the thirteenth century was the central mart of the Hanseatic League, and in the fourteenth century became the metropolis of the world's commerce. Its population at this time amounted to upwards of two hundred thousand. Lübeck, Hamburg and Bremen were Hanseatic towns whose dictates could guide the policy of Europe. In the fifteenth century Bruges declined and Antwerp gained in importance, so that in the beginning of the sixteenth century it was the commercial capital of the world. These great populations, devoted to commerce and industrial pursuits, had but little time to give to the refinement of life, and it is but little wonder if in these densely crowded and rude communities, living in low-lying country with a cold and bleak climate, rickets found a ready habitat.

As will be seen later, in England there is a good deal of actual evidence to be derived from collections of bones throughout the country, which helps to fix the actual date of the origin of the disease within fairly definite limits.

Notwithstanding the fact, then, that Glisson first described the disease in England in 1650, the probability is that rickets was prevalent in Flanders and the Netherlands

some considerable time before it became an important factor affecting the health of the English community.

It is interesting to note that Glisson considers rickets a disease of the rich, bred by luxury. This is probably true in so far as the rich would be the first likely to come under the vicious influences which tend to produce the disease.

In earlier times the general plan of life pursued by our ancestors was more wholesome than that of our own time. One of the worst features of the life was the total neglect of sanitary precautions which was a prolific source of disease. Writing on January 30th, 1453, Margaret Paston writes to John Paston *: "There is no space beside the bed, though the bed were removed to the door, to set both your board and your coffers there, and to have space to go and sit beside." When it is considered that this room referred to was a draught chamber, that is it contained a privy, the want of space was indeed a serious objection. But in most other ways their life was healthier than the mode of living to-day. They were early risers. Artificial lights did not tempt them to steal from the hours of rest the time for either dissipation or study. Dinner was at noon and after dinner it was customary to take some additional rest. Even labourers indulged in the afternoon rest, and by Act of Parliament it was restricted in their case to a quarter of the year, from the middle of May to the middle of August.† Food was coarse and without much variety when compared with the diet of the lowest class of our population to-day. In the long winters the ordinary commodities were not easily obtainable by the very poor, and hunger and starvation were not uncommon. But such is not the type of life that leads to rickets. Their work was in the fields, and while it was light they lived much in the open, for there was not much comfort to induce them to remain indoors except for sleep. Not only the head of the house worked on the land, but the mother and the children as soon as they were able took part in the labour of the field.

* "The Paston Letters," 1422-1509 A.D., edited by James Gairdner, London, 1904.

† *Loc. cit.*

Glisson correctly maintains that rickets is not a congenital disease but is the result of environmental conditions which operate on the child soon after birth. But he believes that certain conditions in the life of the parents may render the offspring prone to the disease.

“ These,” he says, “ are first, the soft, loose, and effeminate constitution of either or both parents. . . . Secondly, an over-moist and full diet. . . . Thirdly, a delicate kind of life abandoned to ease and voluptuousness, slothful, and rarely accustomed to labour, danger, and care. Hither you may also refer a total defect of manly exercise, immoderate sleep, especially soon after meat, and any kind of sleepings whatsoever, a sedentary, speculative life, intent upon soft and quaint arts and sciences, as poetry, music, and the like ; to these may be further added daily frequenting of comedies and other plays, an assiduous reading of fables and romances, and instead of manly recreations a loose expence of time in carding and dicing. . . . We affirm that the rifeness of this disease in England hath been much promoted by that long and secure peace . . . for by this the more wealthy families which were first invaded by this evil, and which doth still invest them more than others, had addicted themselves to idleness and a loose effeminate life, and therefore they fall into a moister, softer, and degenerate constitution and such as was less purged and cleansed from excrementitious humours.”

Answering his own question as to why rickets is more frequent in the southern and western parts of England, than it is in Scotland and the northern counties, he shrewdly remarks that there are probably many mild cases in Scotland and the northern counties which are not recognised ; but he explains the increased prevalence which he believes to exist in the south-west by saying : “ The cause of this difference is the affluence of all good things in these southern and western counties of England. For this part of the kingdom is much the more fruitful, rich and flourishing and abounding with all manner of allurements to pleasure.”

What was true of these counties in Glisson's time remains

true to the present day. Devon, Dorset and Somerset still remain rich fertile counties famed for their dairy produce. The farms and farm labourers are prosperous and their tables are well supplied with rich and wholesome food, and yet the disease is still quite common all over the south-western counties of England. To-day rickets is not so prevalent amongst the wealthy in these counties as it was in Glisson's time, though it is still by no means uncommon, nor is the disease of so severe a type. But it is, to this day, a well-marked affection, and has a far-reaching influence on the physical and mental growth of the children affected.

It is always a matter of surprise, though by no means an uncommon experience, to find that in beautiful country surroundings with an amplitude of fresh air and most excellent feeding, the children are frequently backward in teething, in walking and in speech; later they tend to be dull in school, heavy of feature, and prone to the development of adenoids and mouth breaking. Any one acquainted with the west country knows how the wider stretches of Dartmoor and Exmoor suddenly terminate on a sharp line, as it were, and slope rapidly down into rich pastoral and agricultural land. In Somerset, for instance, there is a beautiful stretch of hill country lying between the Quantocks and the Brendon Hills and Exmoor on the one hand and the Bristol Channel on the other. It consists of hill and vale and all the conditions would seem to make for health. It is as rich pastoral country as any to be found in England; the stock on the farms, cattle, sheep and horses, are in beautiful condition; milk, butter, eggs and vegetables are in ample supply. Yet on these farms, and not only in the families of the farm labourers, it is quite common to find the stigmata of rickets well marked in the children. The mothers nurse their infants at the breast, and if by any chance there is a failure of the mother's milk, there is abundance of dairy supply to meet the deficiency. With the present high prices of milk and butter the supply to the farm labourers is not so ample as heretofore. Separated milk is largely used for the purpose of the household because it is cheap and plentiful, but

this is used for the older children. As a rule the infant has the best of everything. Separated milk is not an unwholesome diet, and even a high degree of separation does not destroy its nutritive value, even from the point of view of fat, when it is supplied in quantity. The farm labourers keep chickens and supply their own vegetables; cheese, bread, and butter are commonly seen on their table. Pork and bacon are more often used than beef and mutton. It is difficult to understand how rickets can develop under such conditions.

The explanation is to be found in the defective home surroundings of the young infant. Farm labourers' cottages are built more with a view to readiness of access, and to suit the convenience of the builder, than from any broad consideration of the principles of healthy living. As a rule the cottage is built down in the valley, frequently close to a running stream. In the south-west country there is much rain and in the summer the air in the valleys is stagnant and oppressive and there is a heavy morning and evening mist. The cottages are picturesque, and in Somersetshire, more than in Cornwall, are well and strongly built. But the rooms are small and are often difficult to ventilate, and the cult of fresh air has not yet made its way into the homes of the people. Windows are meant to exclude air and are not used for the purposes of ventilation. The winters are long and severe, and the roads are only to be attempted with difficulty owing to the mud from the rain and snow. In the case of an infant born in the month of October, the probability is that, for the winter months, it will be confined practically to one room.

It cannot be too clearly understood that, even with the best hygienic surroundings, it is possible, in a climate such as that of England, to reproduce all the vicious environment of a slum. Rickets resembles goitre and cretinism in its habitat, and the valleys lying between the hills are likely localities for both diseases. Slighter conditions of goitre are by no means uncommon at the present day in the county of Somerset and cretinism is not unknown.

Defective and carious teeth and hypoplasia of the enamel are quite common in Somerset, certain evidence of serious interference with the child's growth during the first two years of life.

Local variations are of interest. Thus the children in the little seaport towns of Watchet and of Minehead suffer less severely from rachitic conditions than the children of the farm labourers who live, perhaps, only six or seven miles away. Both these seaports are pleasantly situated on a rising slope facing the Bristol Channel, and, though the conditions approximate those of a town, the houses are well ventilated from the sea, and the children are much less likely to suffer from continuous confinement during the winter months than are the infants who live further inland in the hilly parts behind. Both these small ports are comparatively free from rickets, while in adjacent towns, such as Bridgwater, Taunton and Dulverton in Somerset, extending to Witheridge, South Molton and Torrington in Devon, rickets is prevalent. It must be noted that the disease is not more common in this part of Somerset than it is elsewhere in the south-western counties, as has been shown in discussing the geographical distribution of the disease. In Padstow, a fishing and seaport town at the mouth of the River Camel in North Cornwall, rickets is prevalent. The main part of the town lies huddled at the foot of a hill and a good deal of the house property approximates what might be expected in the slum area of a large town.

A factor worthy of note in discussing the development of the people in the south-western counties is the intermarriage which takes place in the country districts of Somerset and still more markedly in Cornwall. Some of the harmful effects of marriages between first cousins are said to be marked decrease in fertility and a high infantile mortality. Deaf mutism, insanity, albinism, hare-lip, and other deformities are said to occur with greater frequency than among the general population. In South Africa, especially among the Dutch, marriages within the family are quite common,

so that in certain communities one or two names may be the prevailing names of the district, and all the members having one name are more or less closely related. The motive of these marriages is to some extent a desire to keep land within the family. Prevalence of certain names is also seen in Cornwall, though to a less extent than in South Africa, where the communities are more isolated. In South Africa, however, rickets never results, for the conditions are not present to produce the disease even in a defective offspring, and often under the gravest disabilities as regards healthy feeding. Such conditions as talipes equino-varus and certain degrees of mental deficiency are, however, not uncommon. It is not unlikely, however, that this in-breeding, while it cannot itself produce rickets, may so weaken the offspring as to render it less resistant to the influences of an inimical environment, and therefore more prone to the disease if the conditions are favourable to its development.

CHAPTER XX

Ancient Medicine and Rickets

MUCH has been made of a few allusions in ancient writings to show that rickets was a disease known from the earliest times.

Sir Thomas Barlow * suggests that it is coeval with civilisation. This is too wide a generalisation. The accumulating evidence would tend to show that it was unknown in the ancient civilisations of Babylonia, Egypt, and India. Rickets is a disease of civilisation, it is true, but it would be more accurate to say that, considered from a historical point of view, it is a disease of industrialism, and is intimately associated with the growth of great towns in Europe, during comparatively recent times. As already remarked, probably Glisson's computation that the disease originated in England about the beginning of the seventeenth century was not far from the truth. It would be unwise to maintain that the disease did not occasionally occur at any period of the world's history. Doubtless, if a child one or two thousand years ago had been exposed to the conditions which now produce rickets the disease would inevitably have developed. According to Findlay the earliest known example of rickets in man or the lower animals occurred in the ape. Lortet, of Lyons, described the disease in the remains of apes which had been kept captive in one of the temples of Thebes, and as Findlay remarks: "Should such be indeed the case it would cause us no surprise, as in modern times young monkeys kept in captivity are liable to develop rickets." † It must be freely allowed that rickets may have occurred and

* Barlow, "Keating's Cyclopædia of Diseases of Children," Vol. II., p. 224.

† "A Study of Social and Economic Factors in the Causation of Rickets," by Margaret Ferguson, M.A., with an Introductory Historical Survey by Leonard Findlay, London, 1918, p. 12.

probably did occur in individual cases at any time in man's history, but the point is that the conditions which give rise to the disease, as we know it, did not exist till a comparatively late period in the world's history.

The more closely the writings of the ancients are examined, the more strongly is the conviction carried home that the disease was unknown to them. This is the more noteworthy in that the malady is one which would not be likely to have escaped their skilled and accurate observation. Rickets is a striking disease which is not easily missed. Dwarfs and those with physical deformities were ever objects of interest to men all the world over, up to quite recent times, and the absence of allusions to anything that can be fairly construed to signify rickets is very striking. The Hippocratic system of medicine was essentially dependent on observation, and it is not likely that so distinctive a disease would have escaped the notice of both Hippocrates and Galen if it had been prevalent in their time.

Hippocrates (460 B.C.), in his work on "The Articulations," deals at some length with deformities of the spine. Galen, who lived during the second century of our era, in his commentaries on this thesis of Hippocrates, also deals very fully with spinal curvature.

Hippocrates divided curvatures of the spine from internal causes into three varieties: (1) posterior projection of the spine or gibbosity, named by Galen, *kyphosis*; (2) anterior projection of the spine, to which Galen gave the name of *lordosis*; (3) lateral curvature or *scoliosis*.

Speaking of the posterior projection of the spine, Hippocrates says: "When the gibbosity comes on in infancy the growth of the body is not stopped; in this case, the spine does not follow the progress of growth, but the arms and legs develop completely, all being thinner. If the hunch is above the diaphragm, the ribs do not develop in width, but in front; the chest becomes beaked instead of flattened. There is difficulty in respiration and hoarseness; for the cavities which receive and send back the breath are less ample. Further, these individuals are forced to hold the

neck projecting forwards about the axis, so that the head does not hang, and this bone tends to contract the throat greatly by its inclination in this manner. . . . Most often, the individuals so affected, have in the lungs tubercles, hard and coarse, so that the cause of the gibbosity is that the tubercles are in communication with the spine through the vertebral ligaments. When the gibbosity is below the diaphragm the kidneys and bladder may be affected. The hips are thinner than when the gibbosity is high ; the pubis and skin acquire hair more slowly and less completely, and there is less procreative power than when the gibbosity is high." It is quite clear that in these cases Hippocrates is dealing with caries of the spine. The extension of the disease from the lungs to the spine by direct continuity by means of the ligaments is confirmed by Galen. One slight passage might be construed as referring to rickets in which he says : " In some also the attitude assumed in bed contributes conjointly with the malady to produce lateral curvature. But," he remarks again, " these conditions will be spoken of in connection with disease of the lungs."

In his thesis " On Airs, Waters and Places," Hippocrates, speaking of the effects on the inhabitants of a city which is exposed to hot winds, states : " Infants are subject to attacks of convulsions and asthma which they consider to be connected with infancy and hold to be the sacred disease (epilepsy)."

It is a matter worthy of note that Hippocrates lays the greatest stress on the importance of environment in the production of disease, and nowhere is this more directly seen than in this treatise. To-day but little attention is paid to such conditions ; for many years the only environment which has interested medical thought has been the microbic one. There has been a complete swing of the pendulum to the other side and environment is thought to have little, if any, influence on germ plasm. Heredity is held to explain everything and to be responsible for all that befalls man, whether for good or ill. There is a tendency to a complete divorce between heredity and environment as if they

were opposing or at least dissociated factors. But heredity, while it makes for continuity and opposes needless change in response to constantly shifting conditions, itself shows variation, and this can only be in response to environment ; indeed, heredity is but the sum of the response of the organism to environment. The stress only requires to be applied long enough, and the response is certain. Circumcision is a factor without significance in the ontology of the organism, and as such can only have the slightest influence on the germ plasm. If continued long enough it is conceivable that it might produce its effect in the course of the ages and absence of the foreskin might become an inherited quality. Certainly, the influence to be expected in a few thousand years is negligible.

But it is otherwise when conditions of environment which threaten the germ plasm are concerned and where the race continuity is endangered. The growth of large towns and life in confined dwellings have, with the rapid extension of industrialism, profoundly affected the greater part of our population, and already within the last three centuries there has been a marked effect produced on the industrial nations of Europe. Not necessarily an improved race, but a people better fitted to survive under a vicious environment is being produced. It is reasonable to suppose that in rickets, as indeed Glisson held, the child is born, not with the disease, but with a debilitated constitution which will adapt itself better to its evil surroundings than would the healthy and strongly resistant individual. There is no true cleavage between heredity and environment. If the debilitated offspring of the slum dweller is suitably fed and placed in wholesome surroundings, rickets will not develop, but it must be remembered that the greatest care may be taken with the feeding of the infant, and yet the best breast milk in the world will not prevent the onset of rickets if the child is kept month after month in a damp and sunless basement, and in a vitiated and polluted atmosphere. Such is a matter of common experience, but fortunately the reverse side to concentration in great cities has also been taking place over a similar period in our colonial expansion, where the effete and

worn out products of our towns have been rejuvenated in a larger and healthier environment.

The converse is also true, for if the child be brought up under open-air conditions, exposed to fresh air and bright sunlight in a mild and warm climate, no errors in feeding will produce rickets. Marasmus may, and frequently does, supervene; dysenteric affections may carry off the child, and tuberculosis may be prevalent as it is in many of the populous cities in the East, but the characteristic signs of the rachitic state will not develop.

In the "Aphorisms," Hippocrates states: "At the approach of dentition pruritus of the gums, fevers, convulsions, diarrhoea, especially when cutting the teeth, are apt to occur and chiefly in those who are particularly fat and have constipated bowels." The very fullness with which Hippocrates and Galen deal with conditions of the bones and joints without referring to anything which resembles true rickets is valuable negative evidence that the disease did not exist.

Soranus of Ephesus, the biographer of Hippocrates, to whom we are indebted for most of the facts we know of the life of Hippocrates, lived between A.D. 98 and 138. In one passage in the work of Soranus on "Diseases of Women," Findlay believes he has found a true description of rickets.* It runs as follows:—

"How should the child be trained in standing and walking?"

"When the infant makes attempts to sit down and stand up, one must assist his movements. For should he show eagerness to sit sooner than is right or too often, he becomes hunched, owing to the backbone bending while as yet the body has no sinews to resist the strain. If he continue to stand up with growing impetuosity, and wish to walk about, his legs commonly become twisted at the thighs.

"Why the majority of Roman children are distorted."

"This is observed to happen more in the neighbourhood of Rome than in other places. Some suggest as a reason that the city is undermined by cold waters and that their (*i.e.*,

* *Loc. cit.*, p. 9.

the children's) bodies are easily chilled. Others suggest the frequent sexual intercourse of women, or intercourse taking place after a drunken bout. The truth of the matter lies in inexperience with regard to the rearing of children ; for women in the city have not so great a love for their children as to have regard to every particular as the women of purely Greek stock do. If no one oversees the infant's movements his limbs do in the generality of cases become twisted, for the whole weight of the body rests on the legs, and the floor or pavement on which he walks is hard and unyielding, being for the most part laid with stones. When, therefore, he rests upon a hard substance, the weight pressing on the limbs is great, and the limbs which bear him up are frail ; the limbs must then of necessity give way a little, since the bones are not yet stiff. Hence, when he first begins to sit he must be propped up by swathings of bandages to counterbalance the ills that can gain the mastery over him, nor must he sit for long at first. As he advances farther to the stage of creeping and standing up for a little, then one should place him up against a wall and leave him alone. But for purposes of making him approach use a chair on wheels. Thus from a gradual common growth of all the members he will practise walking. So much for movement."

The passage is interesting as illustrating what was a common and well-nigh universal belief which did much harm to the growing infant for many centuries. It was believed that the infant's body and limbs had to be trained into the way in which they should grow. Such a thing as free play of the limbs was entirely discouraged ; and Soranus, in pursuit of his belief, that if the child is left unrestrained, the weight of the body will inevitably cause bending of the spine and later of the legs, recommends the swathing of the infant by binding the whole body in bandages. With regard to the nourishment of the child, Soranus is also meddlesome. He recommends that the infant should be given no food for two days unless it be a little cooked honey. Nursing should begin on the third day, but for the first twenty days not by the mother, but by a nurse. In the absence of the nurse, the

child should have honey and goat's milk for this period. So long did this superstition persist, as to the supposed danger of leaving the child the free play of its limbs and the necessity of swaddling the infant effectively with bandages, that it was not till that remarkable man Jean Jacques Rousseau inveighed against this practice in the year 1762 that the custom was first seriously attacked.

Like Voltaire, Rousseau was immensely interested in medical and physiological subjects and wrote much on them. Both these great writers collected material from far and wide and, unlike the majority of physicians of even that late period, they had entirely thrown off the trammels of ancient theory and tradition. Their deductions founded on a nice discrimination of information garnered from all sources, with a shrewd observation of human behaviour, led them to champion explanations which have stood the test of time and showed them to be original thinkers far in advance of their day.

In England swaddling was never a common custom, but elsewhere throughout Europe the practice was very prevalent. In a passage in "Emile," * pregnant with sound physiology, Rousseau states: "The child has hardly left the mother's womb, it has hardly begun to move and stretch its limbs, when it is deprived of its freedom. It is wrapped in swaddling bands, laid down with its head fixed, its legs stretched out, and its arms by its sides; it is bound round with linen and bandages of all sorts so that it cannot move. It is fortunate if it has room to breathe, and it is laid on its side so that water which should flow from its mouth can escape, for it is not free to turn its head on one side for this purpose. The new-born child requires to stir and stretch his limbs to free them from the stiffness resulting from being curled up so long. His limbs are stretched indeed, but he is not allowed to move them. . . . Thus the *internal impulses* which should lead to growth find an insurmountable obstacle in the way of the necessary movements. The child

* "Emile ou De l'Education," par J. J. Rousseau, Citoyen de Geneve, Amsterdam, 1762.

exhausts his strength in vain struggles, or he gains strength very slowly. He was freer and less constrained in the womb ; he has gained nothing by birth. The inaction, the constraint to which the child's limbs are subjected can only check the circulation of the blood humours ; it can only hinder the child's growth in size and strength, and injure its constitution. When these absurd precautions are absent, all the men are tall, strong, and well-made. When children are swaddled, the country swarms with the hump-backed, the lame, the bow-legged, the rickety, and every kind of deformity. In our fear lest the body should become deformed by free movement, we hasten to deform it by putting it in a press."

It is not probable that constraining the child's limbs would ever in itself produce rickets, as Rousseau suggests, but there can be no doubt of its influence in preventing and retarding the proper growth of the young infant. Where the conditions conducive to rickets prevail, it would undoubtedly render the infant more liable to the disease and would seriously aggravate the attack.

It is worthy of note that in early childhood, when growth is taking place rapidly and there is an employment of energy demanding constant repair, that the assimilative processes are not easily over-taxed. The appetite is large and, provided the food is wholesome, the system easily rids itself of excess. Most of the maladies which affect infancy are not so much diseases in themselves as a failure in the processes of growth and development, and in rickets the disease arises in response to gross errors in the environment. Gastro-intestinal infections are not common in breast-fed infants, nor are the acute eruptive fevers. Characteristic diseases of infancy are such conditions as marasmus and rickets.

In later life, on the other hand, there tends to be a failure of the system, not in the process of assimilation, but in that of excretion—in the getting rid of the waste products which have accumulated as the result of the body metabolism. Gout, errors in the renal secretion, failure in the functions of the liver, are apt to occur.

It is a striking fact that ancient literature does not deal with the diseases of infancy and early childhood as we now know them, but concerns itself mainly with the diseases of adult life and old age. The probability is, that in the best periods of the Greek and Roman civilisation, with simpler conditions, abundant food supply and an advantageous climate, disease in infancy was not so prevalent as it is now. The ancients were acute observers, for the whole of their art depended on observation, rather than on dissection and experiment, and had such diseases been prevalent they must have attracted their attention.

At no time in the history of the world has hygiene reached so high a level as it did during the best periods of the Greek and Roman civilisations. In Greece especially the care of the infant was begun, as it ought to be, from the earliest period of the mother's life. The diet, daily exercise and general physical culture of the girl, were regulated with a view to fitting her for the healthy exercise of her maternal functions. The greatest care was devoted to the expectant mother. Her diet was prescribed according to the dictates of experience, proper exercise was entailed, and she was surrounded with comfort and elegance. Care was taken to avoid anything which could, through the mother, impress the infant unfavourably. From early childhood to manhood the children were systematically trained in daily exercises under experienced teachers. Much attention was paid to the hair and the hygiene of the skin. The great offices of State were concerned with important matters of hygiene, such as town planning and the proper building of houses and streets to get the maximum benefit from the sun. The supply of wholesome water and the general principles of dietetics engaged the earnest thought of the government.* It is usual to regard ancient states as ideal forms of existence, when usually they were quite the reverse. But it is true that in Greece the summit of physical

* "The Hygienic Idea and its Manipulations in World History," by Professor Karl Sudhoff, University of Leipzig, "Annals of Medical History," Vol. I., No. 2, Summer, 1917.

excellence was attained and the virility and powers of resistance of the whole nation were enormously enhanced. Compared with the attainments of Greece and Rome, the extolled cult hygiene of the Egyptians, Babylonians, and even of the Jews, falls very far behind.

The general idea that ancient races belonging to such civilisations as that of Babylon and of Egypt lived a long life of leisured ease and measured toil is far from the truth. In an extensive examination of bodies from ancient Nubia and Egypt the somewhat surprising result was obtained that osteo-arthritis, in all its various stages, from lipping of the articular edges of the bones to complete ankylosis of the spine and of the other joints, was prevalent to a degree unknown in the present day.* The disease was of an exceedingly severe type and affected the joints at an early age, even in the third decade. Tubercle, syphilis, and rickets, are all diseases which tend to leave abundant traces of their presence in the skeleton. In some six thousand bodies Dr. Wood Jones found no traces of these diseases, and in his opinion these three pathological factors, which are so terribly prevalent to-day, were almost unknown in ancient Nubia and Egypt from Predynastic times to the first few centuries after Christ. No evidence of malignant disease was found, and they were wonderfully free from sepsis and practically exempt from early decay of the teeth. Wood Jones also found, what has been noted in other surveys, that the proportion of bodies of young persons found was very much smaller than would be expected from the relative rate of incidence found at the present day in adult and infantile mortality. Such evidence must be received with caution, because there may be other explanations than a small death rate for the relatively small proportion of young bodies. The bodies of young children tend to be less enduring than mature bodies, and possibly the same amount of care was not expended in their preservation. Taking these and

* "The Archæological Survey of Nubia," Report for 1907-1908, Vol. II., by G. Elliot Smith and F. Wood Jones, Cairo, 1910. "General Pathology (including Diseases of the Teeth)," by F. Wood Jones.

other facts into account, however, Wood Jones believes that this disproportion represents a true index of mortality in these ancient times, and he suggests that the findings show that the death rate of young persons was less than a fifth of what it is in Egypt to-day.

If this is accurate, the facts are suggestive and tend to confirm the opinion already expressed that the infants of races living a free and primitive life, are not subject to many of the morbid conditions which accompany a state of civilisation. The conditions tell in favour of the young child, and diseases of nutrition and growth are less common, but, in the adult, the severity of the conditions has a prejudicial effect and conduces to the early onset of diseases, such as chronic arthritis and atheroma, and tends to shorten life. Mr. Elliot Smith strikes a note of caution as regards the reputed absence of rickets in these ancient cemeteries, and believes that many bones exhibit distortions difficult to explain except through the medium of rickets. "It is common," he says, "to find peculiar, though slight, bending of all the long bones. One naturally thinks of rickets as the causal agent, and it is quite possible that this suggestion may ultimately be justified; the reason for hesitation in adopting such a view is that clear, unmistakable evidence of rickets has not been found in human bones in any cemetery in Egypt or Nubia." Later, however, after making due allowance for possible errors, the same observer writes that "he is extremely doubtful whether rickets ever really occurred in ancient Egypt," and he considers that "Ruffer, not being aware of the extent to which the perfectly normal femur can be curved, imagined he had found rickets in ancient remains from the Soudan." * It is possibly not justifiable to say that rickets, tubercle and syphilis did not exist, as the result of the examination of these six thousand bodies, but it is certainly justifiable to say that they were far more rare than they are to-day.

In Europe, north of the Alps, the same opportunities have

* "Introductory Historical Survey to a Study of Social and Economic Factors in the Causation of Rickets," by Leonard Findlay, London, 1918.

not existed for the examination of old-world bodies. In bones from the shores of the Baltic Sea, and in primitive German skeletons, Virchow made his well-known observations on cave-gout (Höhlengicht), a condition which affected both man and beast. Osteo-arthritis was found to be exceedingly prevalent.

In the crypt under the church at Hythe, near Folkestone, as will be more fully noted later, lie the bones of some four thousand people, in an excellent state of preservation, dating probably from the thirteenth to the sixteenth centuries. Examples of osteo-arthritis of a severe type are very common and these peoples must have suffered greatly from the condition.

No diet could well be more varied than amongst these various races living along the banks of the Nile, the shores of the Baltic Sea and the south coast of England. One factor was common to all, namely, that the life of the people was largely spent in excessively damp surroundings. These were all sparse populations and their lives must have been associated with great hardships. It is interesting to note that in all these cases with this exceedingly extensive bone disease, rickets is practically an unknown factor, and, indeed, so far as the evidence of the teeth, jaws, skull and long bones is concerned, it is directly against the existence of the disease to any notable extent at any of these periods, if it existed at all.

Celsus, known as the Roman Hippocrates, lived probably in the reigns of Augustus and Tiberius at the beginning of our era. He wrote eight books on medicine, besides treatises on agriculture, rhetoric and military affairs. He deals with caries of bone, but there is no hint in his work of any rachitic condition. He makes the acute observation, which accords with common experience, that in the tender foetus no fat is found and in the mature foetus there is but little fat present. It has been suggested by supporters of the vitamin theory of the origin of rickets that the new-born infant is a store-house of fat and that the reason why such a disease as rickets does not develop during the first few

months is that the infant is living on the store of fat and associated vitamins laid up during intra-uterine life.

There is an error of observation in this suggestion, which is entirely contrary to common experience. In the first few days after birth, after the free discharge of meconium and urine, the child loses weight and the skin tends to be loose and wrinkled, giving the appearance of old age so commonly seen in the young infant. The skin can be picked up in folds and contains but little subcutaneous fat. The first milk of the mother after birth, the colostrum, has a high fat content, but this is of value, not so much as a nutrient, as for laxative purposes. The fat content of the fæces of the infant is always high, ranging from 10 to 20 per cent., while during the first week it is as high as 40 or 50 per cent. After the colostrum has passed the mother's milk tends to be thin and watery, and later on assumes its full fat value. Not till some weeks or months after birth does the child who is well nursed become fat. It is a matter of every-day knowledge in practice, that in children subjected to conditions likely to produce rickets, the disease frequently first reveals itself as an established disease at the same time that the child develops abundant subcutaneous fat, and has the external appearance of looking plump and robust. It is probably not till later, when delay in teething, walking and speech are observed, that the mother seeks advice and the child is found to be the subject of well-marked rickets.

Another error in the above observation is contained in the statement, commonly made, that rickets does not develop until some months after birth. The rachitic process, as a rule, begins immediately after birth, and by the sixth or eighth month the disease has made considerable progress, and has already inhibited and perverted the process of growth, so that pathological changes of a permanent nature result in various tissues of the body.

CHAPTER XXI

Some Parliamentary and Other Records and the Literature of Rickets following the Publication of Glisson's Work to the close of the Eighteenth Century

It has already been noted that rickets was first described as a cause of death in the table of casualties in the Bills of Mortality for London in 1634. These form an interesting record of the health of the nation and of the incidence of disease in the seventeenth century, and not much use has been made of the valuable and suggestive material they contain. In his "Reflections on the Weekly Bills of Mortality for the Cities of London and Westminster and the Places adjacent," Capt. John Graunt brings forward many interesting facts. The following list is selected from the table of casualties in the weekly bills * and for the purpose of comparison the causes of death have been placed so as to show the relative increase or decrease in the number of deaths resulting from various allied conditions :—

Causes of Death in the Cities of London and Westminster and the Places adjacent for the Years 1629—1658.

—	Rickets.	Liver-grown Spleen and Rickets.	Convul- sions.	Teeth and Worms.	Consump- tion and Cough.
1629-1632	D	392	498	1,751	5,157
1633-1636	113	356	1,734	2,632	8,266
1647-1650	780	213	2,198	2,502	8,999
1651-1654	1,190	269	2,656	3,436	9,194
1655-1658	1,598	191	3,377	3,915	12,157

Several interesting features arise from a consideration of these tables. The number of deaths from rickets rises steadily, especially towards the beginning of the second half of the century. This is probably partly due to more accurate

* "National and Political Observations on the Bills of Mortality," by Captain John Graunt, F.R.S., reprinted from the sixth edition in 1676.

diagnosis of the condition which obtained in London as the result of the publication of Glisson's book. This is borne out by the fact that there is a co-existing diminution in the indefinite morbid state placed under the single heading of "Liver-grown Spleen and Rickets." The increase in the number of deaths from convulsions is very notable, from 498 for the four years from 1629-1632, to 3,377 for the four years from 1655-1658. There is also an increase in the deaths from *Teeth and Worms* from 1751 to 3,915 for the corresponding periods. These are both conditions intimately associated with rickets, and, taken in conjunction with the increase in the number of cases actually listed under that disease, show that there was a very remarkable increase in the disease in London during the years 1634-1658.

The large number of deaths directly due to rickets in the four years from 1655-1658 is evidence of the severity of the type of disease which occurred at that time. Rickets is a malady which, in itself, seldom causes death at the present day, and this large mortality bears out the description of the disease as given by contemporary writers; one and all describe it as a serious malady, inimical not only to the health but to the very life of the sufferer. If the first four columns are added together for the period of four years from 1655-1658 over nine thousand deaths are recorded due either directly to rickets or to conditions associated with it. The growth in the mortality from consumption and cough is also notable, a disease which, like rickets, increases in frequency and severity in direct relation to the degree of over-crowding and defective housing.

In the reign of Queen Elizabeth a proclamation of 1580 was designed to check the irregular growth of London, and the placing of mean houses anyhow and anywhere. This proclamation, dated at Nonsuch on July 7th of that year, sets forth that great inconveniences having arisen from the vast congregations of people in London, and greater being likely to follow—namely, want of victuals, danger of plagues, and other injuries to health—she orders that no further buildings shall be erected, by any class of

people, within the limits of the said city, or within three miles from any of its gates; that not more than one family shall live in one house, and that such families shall not take inmates. No idea of the value of fresh air and open spaces occurred to the Legislature, but every now and then the dangers of over-crowding were brought home by severe outbreaks of plague or other epidemic disease, and not infrequently householders were indicted on the ground of over-crowding. Over-crowding which was the rule during Queen Elizabeth's time seems to have grown worse under the Stuarts, and James I. had scarcely come to the throne when he ordered all such houses as had been erected contrary to Queen Elizabeth's proclamation, to be pulled down and demolished. Cromwell went to the extreme measure of ordering a fine of one year's rent against any offender who had erected a house having less than four acres of land attached to it, and of one hundred pounds against any one who had erected a house without land. Many such firm edicts were promulgated to check the irregular growth of London, but as no provision was made for its regular growth, no one took any notice of any of them.

The failure of legislation in this respect was largely due to the fact that it was quite unintelligent. Fear, and not sound hygiene, was at the bottom of all these Acts and proclamations to prevent the growth of London. To show how little Parliament appreciated the rudiments of healthy living the notorious window tax was introduced on March 25th, 1696. At first it was levied only on houses with ten windows and upwards, but in the reign of George IV., 1746, the tax was levied on the several windows of a house. This naturally resulted in the building in of windows by stone, brick, or lath and plaster, for nothing less would satisfy the Act. An Act more directly against public policy could hardly be imagined, and yet it was not till 1803 that the tax was abolished.

Fortunately the present century has seen the adoption of daylight saving by the passage of the *Summer Time Act*, 1916, the first clause of which runs: "During the prescribed

period in each year in which this Act is in force the time for general purposes in Great Britain shall be one hour in advance of Greenwich Mean Time." An exquisitely simple provision considering the magnitude of the changes it involves. The advantages gained by this extra hour of daylight in the best months of the year are of the greatest service to the community and the Act is a health-giving measure to the children and to the infants of the nation. It must be remembered that in a cold, bleak, and damp climate such as that of England, the rearing of a healthy infant is ever an anxious problem and a matter of extreme difficulty. Even under the most favourable social conditions it is not easy to avoid the occurrence of rickets, and in the crowded slums of our great industrial centres, where the infant is confined during the winter months to a sunless and ill-ventilated room or basement cellar, where there is no provision for exercise and the child is constantly breathing a vitiated atmosphere, the disease cannot be avoided. For a long period of the year it is necessary for the mother or nurse to keep watch for every available hour of sunshine. Fresh air in the open is one of the crying needs of the young infant, and the Summer Time Act, by extending the opportunity for such exercise in the open at a time of the year when sunshine and a warmer air are available, is of the greatest value. I know of no measure of equal importance which is fraught with greater benefit to the community and which entails fewer inconveniences than this simple Act.

For a long time after the publication of Glisson's book in 1650 no very notable advance was made in the study of the disease, largely due, as already stated, to the fullness and completeness of the work. Glisson's publication became the model for the ordinary inaugural thesis required for graduation, and in Edinburgh, Leyden, Vienna and elsewhere on the Continent, these were produced in large numbers. Notably in Edinburgh towards the close of the eighteenth century many such theses were published indicating that much interest was being taken in rickets at that period.

By the end of the eighteenth century a great mass of literature had already grown up round the subject, as may be seen from a study of *de Plouquet's Digest of Medical Literature*, published in 1809.* Most of these theses were naturally short papers, usually devoid of original research, and were frequently little more than extracts from Glisson's work. Their chief claim to interest is frequently their age and period. There were, of course, notable exceptions.

John Mayow was such an exception. Mayow (1643-1679) was educated at Oxford, and in 1660 was elected to a fellowship of All Souls. He graduated in law, but made medicine his profession, and in 1678 he was elected a Fellow of the Royal Society. In 1668 he published at Oxford, "Tractatus de Respiratione," and in 1669, "Tractatus de Rachitide," both of which were afterwards published by the University of Oxford in his now celebrated "Tractatus Quinque," † in the year 1674. In this large treatise it is remarkable how many important physiological discoveries are contained. Mayow held advanced views on respira-

* "Literatura Medica Digesta sive Repertorium Medicinæ Practicæ Chirurgiæ atque rei obstetricæ," Guilielmus Godofredus de Plouquet Tubingæ, 1809.

Besides de Plouquet's "Medical Digest," the Index Catalogue of the Library of the Surgeon-General's Office, United States Army, should be consulted by those interested in the history of the disease; the Royal Society of Medicine, the College of Physicians, the College of Surgeons, and especially the British Museum in London, are all rich in the early literature of rickets. Besides the treatises dealt with in the text the following are a few of the earlier works belonging to the seventeenth and eighteenth centuries which I have been able to peruse and handle:—

Schoengast, Christoph. Andreas, "De Rachitide," Leipsic... 1668

Ersfeldius, Nicholas Wilhelmus, "De Rachitide," Helmstadii ... 1682

Vaux, Georgius, "De Rachitide," Lugdini Batavorum ... 1704

Wieseler, Casp. Joh., "De Rachitide," Helmstadii ... 1716

Buchner, J. Petri, "De Rachitide," Strassburg ... 1754

Nooth, Joannes Mervin, "De Rachitide," Edinburgh ... 1766

Bromfield, Wm., "Chirurgical Observations and Cases,"

Vol. II., pp. 25-41 ... 1773

Nasmyth, Thomas, "De Rachitide," Edinburgh ... 1777

Watson-Sproule, Joannes, "De Rachitide," Edinburgh ... 1787

Trnka de Krzowitz, Wencesla, "Historiæ Rachitidis,"

Vienna ... 1787

M. Pouteau, "Œuvres posthumes de," Tome Premier—

Cinquieme Memoire, Paris ... 1783

† "Tractatus quinque medico-physici, quorum primus agit de sal-nitro et spiritu nitro-aero. Secundus de respiratione. Tertius de respiratione fœtus in utero. Quartus de motu musculari et spiritibus animalibus. Ultimus de rachitide." Joannes Mayow, Oxonii, 1674.

tion, and he gave a wonderfully accurate anatomical description of its mechanism. Under the name of spiritus igneo-aereus or sometimes nitro-aereus he discovered the existence of oxygen, and proved by experiment that it was required to maintain the light of a candle, and was also necessary for the maintenance of life by respiration. His work was disregarded and it remained for Priestly and Lavoisier to make the same discovery one hundred years later. Mayow was only thirty-six years of age when he died, and had he lived the normal span, there is but little doubt that he would have short-circuited the discovery of oxygen by a century.

In 1790 Thomas Beddows rediscovered Mayow's work,* and places his name alongside those of Sir Francis Bacon and Sir Isaac Newton. Writing in 1908, Francis Gotch † describes Mayow as one of the greatest scientific men of the seventeenth, or, indeed, of any century. In 1685 an English translation of Mayow's "de rachitide" was published at Oxford.‡ In the preface, written by Mayow himself, he states: "The renowned Glisson is the only man (as far as I know) who hath written anything touching rickets, which may seem to be very strange, since a disease for the most part doth scarcely spread so much as the habit of writing concerning it." Mayow practised in Bath during the summer, where he acquired a considerable practice, and he agrees with Glisson that the disease had its first rise in the western parts of England above forty years ago. The age of invasion of the disease is, he states, from six to twenty-four months. Unlike Glisson, he does not consider rickets a disease of the blood, because if it were he would have expected all parts would be affected alike. He believes it proceeds from an obstruction of the spinal marrow. He accounts for the bending of the bones in a somewhat quaint fashion by supposing that while the muscles and nerves do not grow, as the result of the interference with the spinal

* "Chemical Experiments and Opinions extracted from a Work published in the Last Century," Thomas Beddows, 1790.

† "Two Oxford Physiologists, Richard Lower and John Mayow," by Francis Gotch, Oxford, 1908.

‡ "A Tract of the Disease Rhachitis, commonly called the Rickets," translated into English by William Sury, Oxford, 1685.

marrow, the bones continue to grow at the ordinary rate. The bone being thus held down at each end, becomes bent like a bow of which the contracted muscles and nerves form the cord. The article on rickets is the least important of the five theses published by Mayow. His work on respiration was based on experiment, and his conclusions had gone far ahead of what he could yet prove, though their accuracy was established by later discovery. Mayow was only twenty-six years of age when he wrote "*De Rachitide*," and cannot have had much experience of practice. He followed in the main Glisson's work, and it cannot be claimed that his deductions added anything important to our knowledge of this disease.

In the early part of the eighteenth century, Boerhaave, in his "*Aphorisms*,"* speaks of rickets. He lent the weight of his great authority to Glisson's view that it was a new disease, and thinks it arose about the middle of the sixteenth century, originating in the inland parts of England, from whence it spread throughout the kingdom and over the northern part of Europe, where, he states, it is now a very common disease. In his description of the causation, signs and symptoms, he follows Glisson, and with him believes that it is a disease of luxury rather than of deprivation. It is best cured, he maintains, with a light, dry, less fat diet.

In 1741 J. L. Petit† insisted on early weaning as a cause of rickets. He gives in his treatise a good description of the macroscopic appearances of the diseased bone, and describes the rough inequalities that arise on the surface of the bone, and the increase in volume of the orifices of the blood-vessels.

Levacher de la Feutrie‡ separated rickets from osteomalacia, affections which till then had been confused. "One knows," he says, "that the soft and supple bones of children which become curved from weakness differ consider-

* "*Boerhaave's Aphorisms concerning the Knowledge and Cure of Diseases*," translated from the last edition printed in Latin at Leyden in 1715 by J. Delacosse, London, 1715.

† "*Traité des maladies des os*," J. L. Petit, Paris, 1741.

‡ "*Traité du Rakitis*," Levacher de la Feutrie, Paris, 1772.

ably from the dense and brittle bones of the adult, which bend as a result of softening."

Zeviani, an Italian writer of the eighteenth century, is an authority whose work is frequently quoted.* His treatise was first published at Verona in 1761. Zeviani combats the view that rickets is a new disease, and believes that it was known in ancient times, although he is not able to support his belief. He does not consider rickets a common disease in Italy, but states that it occurs in Lombardy and Tuscany, regions where it is prevalent to this day. No mention is made of the disease occurring in Naples. His views as to the etiology of the disease are of interest in that he was one of the earliest writers to suggest that an acid circulating in the blood was the essential cause of the condition. This acid, he considers, is produced from acrid and sour milk, but he gives no explanation of the formation of any particular acid. Conditions in the parents such as obesity predispose to the disease in his opinion, and mental states such as worry, bad temper, etc., may contribute, presumably through their effect on the milk of the nursing mother.

Towards the close of the eighteenth century Antoine Portal wrote an interesting monograph † in which he states the disease is exceedingly common in Paris and the surrounding country, affecting, he believed, one fifth part of all children. He first stated a view, which has frequently been brought forward since his time, that rickets is not a true entity in itself, but is merely the end result of many diseases.

In accordance with this view he describes six varieties of rickets :—

- (1) the venereal ;
- (2) the scrofulous ;
- (3) the scorbutic ;
- (4) that following eruptive disorders ;
- (5) that accompanying or following intestinal lesions ;
- (6) the rheumatic or gouty variety.

* "Della Cura De' Bambini attaccati Della Rachitide Trattato," del Dottor Giovanni Verardi Zeviani, Napoli, 1775.

† "Observations sur la Nature et sur le Traitement du Rachitisme," par Antoine Portal, Paris, 1797.

In consequence of this view he deals with such conditions as caries of the spine, and tubercular lesions of the abdomen and chest as if they were part of the disease. In the treatment of the disease he advocates the use of mercury for the venereal variety, and he also mentions the use of phosphorus. Change to a pure and dry air at an altitude he considers of value.

In the seventeenth century there is but little record of the life of the great mass of the population except such as can be collected from poor law and prison records. But from the private correspondence of the wealthier classes, which has, fortunately, every now and then been carefully preserved, valuable information can frequently be culled. The lower classes had but little chance of corresponding, even if they had had the ability or the inclination, and most of these letters belong to the higher classes of society. When a servant writes, and there is much excellent writing by trusted servants, the letter is usually concerned with the affairs of the family to which he or she was attached.

One point is very striking in this correspondence, namely, the high mortality which occurred among infants and young children even in wealthy and high-born families, where the conditions must have been as favourable as they could be expected to be anywhere. Not lack of food and attention, but an overweening anxiety and care on the part of the parents was the usual fault in the up-bringing, for life was known to be precarious in children of tender age. The very precautions taken to guard the infant from harm were unhappily the very causes which contributed to much ill-health and a high death rate.

Another factor of importance was the early age at which marriages took place in noble families. The marriage was a matter of arrangement by the parents, and it was quite a common thing for a child to be married at the age of thirteen. Usually in such a case the young wife continued her education for a year or two while her husband went to Oxford or

travelled abroad.* Even so the child became a wife and a mother at a very early age, and both mother and child were exposed to an increased risk during pregnancy and parturition, as the result of the parent's immaturity. If the child were safely delivered the chances of the mother being able to suckle her infant satisfactorily were greatly diminished.

It must be remembered that artificial feeding and the feeding bottle are of quite recent origin. The feeding bottle was not in common use till well on in the nineteenth century. In the seventeenth century the difficulties of the nursery, even in the wealthiest families, were enormously greater than they now are. If the mother's milk failed, no other course was open but to place the child with a wet nurse. From the earliest times in medical writings, instructions were given as to the selection of a suitable foster mother. Galen deals with the subject, and Soranus of Ephesus is very explicit in his directions in his work on gynæcology. In the numerous works which were written for the instruction of midwives, and of the general public, from the times of Thomas Phaire, who wrote the first English nursing manual in 1551,† the choice of a suitable wet nurse is always given an important place. As a result of the demand for wet nurses large numbers of young women became mothers of illegitimate children, who were immediately placed in baby farms while the mothers nursed more fortunate infants. The mortality in these baby farms was enormous. Wet nursing, and its concomitant, baby farming, were great evils in the sixteenth and seventeenth centuries. Cow's milk, as we have already noted, was not used because of the insanitary conditions in which cows were kept. Frequently in London they were kept in foul cellars, and it was found that the infantile mortality from intestinal infections where milk was used was very excessive, and Phaire expressly cautions against its use.

* "Home Life Under the Stuarts, 1603-1649," by Elizabeth Godfrey, London, 1903.

† "The regiment of life, whereunto is added a treatise of the pestilence, with the Booke of Children," newly corrected and enlarged by Thomas Phaire, London, 1553.

The class of mother who is willing to undertake the suckling of another child for monetary gain is not a desirable one. Luigi Tansillo, an Italian writer of the sixteenth century, in his poem "The Nurse" * points out the folly of being—

" Hopeful that pity can by her be shown
Who for another's offspring quits her own."

But there was no alternative between breast-feeding and spoon-feeding from the pap-boat or porringer, which formed so important an article in the nursery of those early times. Many of these in wood, pewter and silver, are preserved in museums to-day.

The memoirs of the Verney family give many interesting glimpses into the life of the times of the Commonwealth and later. Writing on August 10th, 1647, three years before Glisson's book on rickets was published, Mary Verney writes from England to her husband, Sir Ralph Verney, who was in exile in France in the Royalist cause.† "I must give thee some account of our own babyes heare. For Jack his legges are most miserable, crooked as ever I saw any child's, and yett thank God he goes very strongly, and is very strayte in his body as any child can be; and is a very fine child all but his legges, and truly I think would be much finer if we had him in ordering, for they lett him eate anything he hath a mind toe, and he keeps a very ill diett; he hath an imperfection in his speech, and of all things he hates his booke, truly 'tis time you had him with you for he learns nothing heare. You would be much pleased with his company, for he is a very ready witted child and is very good of company, and is so fond of the name of his father and mother." A most excellent and lively picture of the rickety child, direct and plain, such as could not be extracted from the whole of the far-fetched allusions which can be culled from Hippocrates or Galen, or, indeed, from any writer till one comes to Europe about the seventeenth century. Jack Verney at the time this letter was written was nearly seven

* "The Nurse," a poem translated from the Italian of Luigi Tansillo by William Roscoe, Liverpool, 1798.

† "Memoirs of the Verney Family during the Civil War," by Frances Garthnope Verney, 2 vols., London, 1892.

years of age, and was evidently, now that he had forsaken the nursery, with all its pampering and its debilitating influences, taking his own path in life, and was, in consequence, in spite of the continuance of his very ill diet, developing into a strong sturdy boy with that touch of self-will so commonly seen in the older rickety child.

All the Verney children were delicate, evidently from the same cause, and about this time one of two daughters who were sharing the father's exile died at Blois. Nor were his troubles then at an end. Within two months of the date of Mary Verney's letter, on October 3rd, 1647, Dr. Wm. Denton, physician to Charles I., writes to inform the afflicted Sir Ralph Verney of the death of his infant boy in England. "Your own wofull experiences," he writes, "have prepared you for any disorders that any of Job's comforters can present to you, God hath taken away what He gave, I meane your youngest son by convulsion fitts." This child was only a few months old.

John Evelyn in his diary under the date, January 27th, 1657-1658,* records: "After six fits of a quartan ague, with which it pleased God to visit him, died my dear son Richard, to our inexpressible grief and affliction, five years and three days only, but at that tender age a prodigy for wit and understanding." He proceeds with a father's fondness to recount his son's attainments, which were indeed of a marvellous order, including a knowledge of Latin and Greek. In the same entry he states: "In my opinion, he was suffocated by the women and maids that attended him, and covered him too hot with blankets as he lay in a cradle, near an excessive hot fire in a close room. I suffered him to be opened, when they found that he was what is vulgarly called liver-grown." The next entry in Evelyn's diary, February 15th, of the same year, records the death of his infant son, aged eight months. "The afflicting hand of God being still upon us," he states, "it pleased Him also to take away from us this morning my youngest son, George, now seven weeks languishing at nurse,

* "The Diary of John Evelyn," with an Introduction and notes by Austin Dobson, 3 vols., London, 1906, Vol. II., p. 127.

breeding teeth and ending in a dropsy." There was no want of care bestowed in the rearing of these children, indeed, as Evelyn shrewdly suggests, the very excess of anxiety produced by the high mortality in young children defeated its own ends and provoked the very results it meant to avoid. The ordinary cradle of the period, familiar to all up to quite recent times, was a massive wooden structure on rockers. This was piled up with pillows and blankets, and on the slightest approach of cold, was placed near a fire. Windows were made, not for ventilation, but to exclude fresh air, and were kept constantly closed. All the conditions, viz., over-rich feeding associated with defective hygiene, which Glisson presents as contributing to the disease, were present in wealthy families at this period, and it is among these children that Glisson found the disease most prevalent and assuming the severest type. Artificial foods were, of course, at this time quite unknown.

In "*Pædotrophia*," a sixteenth century poem of much interest, by Scevole de Sainte Marthe (1536-1623), which resembles the writing of the Italian poet Tansillo, much excellent advice is given on the rearing of infants. He agrees with John Evelyn that much harm is done by excessive care wrongly bestowed on the young infant :—

" Misguided fondness makes our nurses err
By heating infants, and excluding air
Hence are their limbs relax'd, their spirits weak,
Hence oft the thread of life itself will break."*

The death of the son of Francis the Second Duke of Brittany, described by him, resembles that of Evelyn's son Richard :—

" But, while the parents, blinded by their love,
Who best could rear the child together strove,
While, thus misguided, sedulous they try
From cold to save him, and a wintry sky,
The hapless infant, kept in constant heat,
Deny'd fresh air, and still immers'd in sweat,
Soon breath'd his last ; and they the death lament,
Brought on by what, they hop'd, would fate prevent."

* "*Pædotrophia*, or the Art of Nursing and Rearing Children," a poem in three books, translated from the Latin of Scevole de St. Marthe by H. W. Tytler, M.D., 1797, Book II.

Both these sixteenth century poets, de Sainte Marthe in France, and Tansillo in Italy, were serious-minded reformers, who by their poetry attempted to instruct mothers in their duty to their offspring.

The disease to-day is one which shows a definite tendency to affect chiefly the lower classes of society. Among all classes in the seventeenth century in England rickets was spreading rapidly to the great consternation of the general public. More especially the homes of the wealthy were invaded and the most severe cases were found there. In those ruder times it was only the child of the wealthy who could be effectually screened according to the ideas then prevalent. The fear of miasmatic conditions led to the rigorous exclusion of fresh air from the young infant, and the pampering and coddling of the child in over-heated and badly ventilated nurseries. The feeding was good and the infant was suckled at the breast either by the mother or by a foster mother.

Isaac Walton lived at the same period as Glisson. Even in his well-conducted household in Chancery Lane, Walton—the gentlest of men, assiduous and prosperous in his business—found it impossible to rear healthy children. He was twice married. By his first marriage he had seven children, all of whom died in infancy. Two of the children of his second marriage, however, survived and lived to adult years. In such a home there was no want of intelligent care in the feeding of the infant, but there was a complete ignorance of the value of fresh air and good general hygienic conditions in the rearing of young life. Recurring attacks of plague and other epidemic diseases had led to an excess of care which defeated its own object. Such was a common experience all over England at this time in good-class homes.

Rickets, as with many diseases on their first appearance, assumed a degree of severity which often led to a fatal issue. In the course of the generations, however, the disease became more attenuated, at the same time that it became more diffuse and more widely spread throughout all classes. It suggests the rapid elaboration of a defensive mechanism

which could be readily called into play to meet environmental conditions which threatened the very continuity of the life of the community as a whole.

The feeding of the children of the poor, on the other hand, was often very defective but the general conditions, if more rigorous, were more wholesome for the developing child than in the better class homes. It was not until the great industrial development took place, especially the development of the cotton industries in Lancashire, that rickets became essentially the disease of the common people and of slum areas.

Writing in 1773, Dr. Fordyce makes the following comment on rickets in London in his time. He states *: "I speak within the bounds of truth when I assert that there must be near 20,000 children in London and Westminster and the suburbs ill at this moment of the hectic fever, attended with tun-bellies, swelled wrists and ancles, or crooked limbs, owing to the impure air which they breathe, the improper food on which they live, or the improper manner in which their fond parents or nurses rear them up : for they live in hot bed chambers or nurseries, they are fed even on meat before they have got their teeth, and what is, if possible, still worse on biscuits not fermented, or buttered rolls, or tough muffins floated in oiled butter, or calves feet jellies, or strong broths, yet more calculated to load all their powers of digestion ; or are totally neglected." It is interesting to note that rickets is still held to be a condition associated with surfeit of food, especially of rich foods, accompanied by a tendency to coddle the child in overheated, badly ventilated rooms and houses.

* "A New Inquiry into the Causes, Symptoms and Cure of Putrid and Inflammatory Fevers, with an Appendix on the Hectic Fever and on the Ulcerated and Malignant Sore Throat," by W. Fordyce, M.D., London, 1773, p. 207.

CHAPTER XXII

Economic Factors in Relation to Rickets from Early Times to the Roman Occupation of England

ANCIENT literature is strikingly deficient in anything which would suggest that the writers were familiar with rickets. The very absence of allusion to so definite a disease is, as already stated, valuable negative evidence that the disease was not common, and probably hardly existed at all in those times. Positive evidence bearing out the same fact is not wanting. Rickets is rightly considered to be a general or systemic condition, but the most marked signs of the disease are due to the defective laying down of calcium throughout the body in the early stages of the development of the young infant. In an enquiry into the economic conditions under which ancient races lived, few more useful records can be obtained than is found in the examination of the skeleton, skull and teeth. In rickets the examination is of special value, in that it is on this durable record that the history of the disease is written.

In Egypt systematic examination of ancient burials on a large scale shows, as we have already seen, that diseases of a modern type were quite common. The rate of incidence of various diseases, however, varied greatly from what occurs at the present day. Thus developmental conditions and errors of growth in the infant and young child were of notably infrequent occurrence, while adult types of disease, such as failures of elimination, associated in some cases with evidence of infection, such as pyorrhœa, were quite common. These excavations in Egypt show that the commonalty lived under conditions of great hardship as regards undue toil and defective feeding. But, notwithstanding these facts, rickets seems to have been a disease entirely unknown.

In examining a number of bones it would be misleading to draw any direct inference from the absence of such characteristic signs of rickets as the arching of the tibia at the junction of its lower and middle thirds, or the bowing of the femur, or the enlargement of the epiphyseal ends of the long bones, or the beading of the ribs. In the long bones many of these signs tend to disappear as adult life is approached. The long bones straighten out and the swellings at their epiphyseal ends rapidly diminish, but, as we have seen, certain of the other bony signs, notably the thickening of the skull and deformations of the bones of the face and of the chest and pelvis, often remain remarkably persistent even into late adult life. If, say, two thousand long bones were examined and no rickety signs were found the evidence would be fairly conclusive that the disease had not been present amongst those people. But it would be unwise to lay much stress on the absence of rickety signs from, say, one hundred long bones without further confirmatory evidence. A much more reliable criterion is found in the skull and especially in the jaws and teeth.

As we have already seen, there is a marked tendency in rickets to overgrowth of lymphoid tissues. Adenoids and enlargement of the tonsils are very characteristic of the rachitic state and are most commonly a direct result of it. Mouth breathing, with all its evil consequences, is of frequent occurrence. Besides the deformities of the jaws and the irregularity of the teeth, two other dental conditions are notably associated with the rachitic state, viz. :—

- (1) a tendency to early decay which is exceedingly common and widespread ;
- (2) hypoplasia, or defective development of the enamel, which is present in about twenty per cent. of rickety subjects.

These changes have already been dealt with in previous chapters.

Writing in 1672,* in the work already mentioned, " A

* " English Men of Letters : Sir Thomas Browne," by Edmund Gosse, London, 1905.

Letter to a Friend," and referring to the death of the intimate friend, the occasion of the letter, Sir Thomas Browne observes: "In the years of his childhood he had languished under the disease of his country, the rickets; after which, notwithstanding, many have become strong and active men; but whether any have attained unto very great years, the disease is scarce so old as to afford good observation. Whether the children of the English plantations be subject unto the same infirmity, may be worth the observing. Whether lameness and halting do still increase among the inhabitants of Rovigno in Istria, I know not; yet scarce twenty years ago Monsieur du Loyr observed, that a third part of the people halted: but too certain it is, that the Rickets encreaseth among us." In another part of the same work, Browne makes the shrewd observation: "The Egyptian mummies that I have seen, have had their mouths open, and somewhat gaping, which affordeth a good opportunity to view and observe their teeth, wherein it is not easy to find any wanting or decayed: and therefore in Egypt where one man practised but one operation, or the diseases but of single parts, it must needs be a barren profession to confine unto that of drawing of teeth, and little better than to have been tooth drawer unto King Pyrrhus, who had but two in his head."

Caries of the teeth certainly existed among the ancient Egyptians. The late Marc Armand Ruffer even makes a statement, from an observation of twenty-four bodies dating from about two thousand years ago, that the liability to decay was much the same as it is now. The number of bodies examined is small, and he notes that the third molar is more often decayed than the first and second. To-day it is the first molar which is most commonly decayed or absent.* In nine coptic bodies belonging to Antinoë in Upper Egypt, dating from the fifth and sixth centuries of our era, Ruffer found serious lesions of the teeth with evidence of pyorrhœa alveolaris. In these studies Ruffer

* "On Osseous Lesions in Ancient Egypt," by Marc Armand Ruffer and Arnoldo Rietti, *Journal of Pathology and Bacteriology*, Vol. XVI., 1911-12.

showed the common occurrence of arthritis, spondylitis deformans, dental caries, rarefying periodontitis, pyorrhœa alveolaris, and, what is most surprising of all, well-marked arterio-sclerosis, which was commonly present.* The association of pyorrhœa, arthritis and arterio-sclerosis suggests the probability of some endemic infective condition affecting the communities from which these bodies were drawn. The suggestion that decay of the teeth was as common in ancient Egypt as it is in England to-day is not supported by other observers. The number of bodies observed by Ruffer is too small, and the areas from which they were drawn too localised to allow of general deductions.

Moodie believes that caries of the teeth is the rarest form of pathology in ancient times, and that early races of man have been singularly free from the disease.†

Turner and Bennett made some careful observations on 435 ancient Egyptian teeth belonging to about three thousand years ago.‡ Unfortunately these were loose teeth and were not *in situ* in the skull. These observers point out the danger of mistaking post-mortem cavities in the teeth for true caries, which Ruffer had evidently done. It is noted that the jaws from which the teeth came were well formed and the dental arches particularly free from irregularity, and that the jaws were also free from evidence of oral sepsis. 16·78 per cent. of these teeth showed evidence of caries. The part of the tooth most commonly affected differed from to-day in so far as it was not present at the abutment point, where adjacent teeth touch, but was most commonly found at the neck of the tooth (58 cases out of 70). In a smaller proportion (12 out of 70) the decay affected the biting surface of the tooth. Discussing the condition of decay in the

* "Studies in Palæopathology in Egypt," by Marc Armand Ruffer, *ibid.*, Vol. XVIII., 1913-14.

† "New Observations in Palæopathology," by Roy L. Moodie, Ph.D., Department of Anatomy, University of Illinois, Chicago. "Annals of Medical History," New York, Vol. II., 1919, p. 241.

‡ "Some Specimens of Caries from Ancient Egyptian Teeth, about 3,000 Years ago," by J. S. Turner, F.R.C.S., L.D.S., and F. J. Bennett, M.R.C.S., L.D.S. "Trans. Internat. Cong. Med. 1913," London, 1914, Sect. xvii., Stomatol., Part 2, 1-5.

teeth as compared with the present day, these observers state that the comparison is overwhelmingly in favour of the ancient Egyptians. This is in accord with the experience of practically all observers. The cause of the better condition of the teeth is attributed by these observers to the fact that the people ate coarse cereals, and it is suggested that the stagnation of coarse granules round the necks of the teeth determined the decay to this site. The usual explanation of decay is that it is due to the lodgment of starchy and saccharine particles from the food, allowing of the fermentation of these substances and the production of acids which act as a solvent to the tooth. It is probable that the cause lies much deeper, and is to be found in the failure of the first defences of the teeth, that is in the actual laying down of the enamel, and one of the commonest causes of this failure is rickets. The bad state of the teeth seen in our great cities, such as Glasgow, is not due to soft water, nor, in the first instance at least, to want of attention to the hygiene of the mouth, but is due to the extraordinary prevalence of rickets which interferes with the regular laying down of the enamel. Another explanation of the decay in the Egyptian teeth may be, as already suggested, that it began as an infective condition affecting the gums, and this may have determined the locality of the decay to the neck of the tooth. In any case a large part of the immunity from caries of the tooth among the ancient Egyptians, as compared with the population in England to-day, is to be found in the absence of rickets. In all these observations from Turner and Bennett, and from Ruffer, there is no suggestion of rickets. Indeed the well-formed dental arches and regularity of the teeth indicate that this disease did not affect these people, though there were extensive signs of other bone affections such as osteo-arthritis.

So common is the tendency to early decay of the teeth and malformation of the dental arches and hard palate in the rachitic state, that if in a large series of crania it is found that the dental arches and palate are well developed, the full number of teeth present and not decayed, though they

may be, and usually are, much ground down, if the edges of the teeth meet and do not overlap, and if hypoplasia is absent, it is safe to infer that rickets was not a disease which affected these people. If one hundred skulls were examined from one community without any other bones of the skeleton, a very accurate opinion could be formed as to the presence or absence of rickets.

Now the condition of the jaws and teeth just described is characteristic of the crania of nearly all the primitive races and of the native races to-day still living in their natural state. Still more striking is the fact that up to about the beginning of the seventeenth century the same type persists in England, and from that time forwards the jaws and teeth begin to assume the modern type. Indeed, so widespread is the disease, that there can be but little doubt that a profound change has actually occurred in the formation of the skull within comparatively recent times, say, from about the beginning of the seventeenth century, with a tendency to produce the lantern-jawed type of individual with a deformed upper and a diminished lower jaw. This change, which, according to our present nomenclature, must be termed pathological, is in reality a normal response to an altered environment, and is a factor which must be taken into account in measurements of the skull by anthropologists.

In 1603, 319 years ago, Queen Elizabeth died, and at that time the population of England and Wales is estimated to have been $3\frac{1}{2}$ millions. To-day the population is $33\frac{1}{2}$ millions, and the strain of life has increased enormously under modern conditions. So large a growth of population in a restricted area, in so short a period, called for a tremendous readjustment and for a great power of adaptability. The whole trend of life was altered. In place of a series of comparatively small communities scattered all over England, each of which was compelled to be largely self-supporting owing to the very limited means of distribution, a vast industrial England arose where whole towns and districts specialised in supplying the needs and wants of other sections of the

population. At first each community lived almost entirely on the land. Each family supplied its own wants, even to the spinning of the wool necessary for the making of the clothes of the family. The husband worked as a labourer on the farm, while the wife and children were employed with the work of the house and on the plot of ground which surrounded it. The life was strenuous but was healthy.

In industrial England, on the other hand, the people were drawn from the land into the towns; in place of the wife, with the aid of the elder children, contributing her share to the support of the family by work in the home or on the plot of ground surrounding it, all were compelled to take their place in the factory to earn sufficient money to supply the bare family needs. The enormous populations of the towns had to be housed, and this was done in dwellings destitute of comfort and devoid of any idea of hygiene or of healthy living in their construction. Jerry-built houses placed back to back and noisome courts and alleys became common features of the larger towns, and all over the country these slum areas remain features of our large manufacturing towns to-day, forming a constant menace to the health of the population and extorting an enormous penalty from young infant life in a high mortality, and irregular and stunted growth in the children who struggle through. Food, while the population depended on the farms, was wholesome and usually fairly abundant, and the clothing was made at home. In the industrial populations everything had to be bought, and food and clothing were dear. Besides being dear the food was poor in quality and was frequently adulterated. In many respects the failure of the population to adapt itself to so wide and so vast a change was fairly complete, and it is from this failure that we are suffering largely to-day.

A study of what have been well termed the four elementary requisites of national healthiness, namely, food supply, house accommodation, physical surroundings and industrial circumstances, as they affected the people of England before the seventeenth century and after, cannot fail to be of value in helping to elucidate the causes for these changes.

Sir Arthur Keith, in his recently published work on "The Antiquity of Man," speaking of the Coldrum collection of Neolithic men, draws an interesting comparison between Neolithic and modern man as regards their teeth.*

"Amongst modern Kentish folk, as is the case all over modern Britain, there is a tendency to crowding and irregularities of the teeth; the palate and jaws do not grow and expand sufficiently in youth to give room for a symmetrical eruption of the teeth. The nose is narrow and the palate contracted, and its vault is high. The teeth are not worn down as in Neolithic men; they are very liable to be attacked by caries. The front teeth, when the jaws are closed, do not meet edge to edge as in primitive races; like the blades of scissors, they overlap, the lower passing behind the upper. In the Neolithic people all these modern characters are absent. Abscesses or gum-boils at the roots of the deeply-ground teeth were, however, common; but there is not a single carious tooth to be seen in the Coldrum collection. The teeth are regular in their arrangement, the palates were well formed, but in actual size the teeth possess the same dimensions as those of modern English people. All these changes, which are appearing in the teeth and jaws of modern British people, arise, we suppose, from the soft nature of our modern diet. We believe that were modern men to resume a Neolithic diet their teeth and palates would again be moulded in the ancient manner."

The difference is, however, hardly capable of such easy solution. Rickets was probably a disease unknown among Neolithic infants, as is largely the case among native races to-day, notwithstanding frequent privations as regards food. Contrast the life of Neolithic men living under primitive conditions, rising with the sun and going to rest at sunset, and living in small communities scattered over wide areas, with that of the slum conditions under which so large a proportion of our population lives to-day.

Loss of function of any organ naturally impairs its development, but the causes of hypoplasia and the tendency

* "The Antiquity of Man," by Arthur Keith, London, 1915.

to early decay of the teeth must be due to other causes than the neglect of the proper use of the teeth and jaws. Making a rough estimate, I would say that 90 per cent. of the cases of failure in the formation of the enamel in the second dentition occur as the result of errors of growth in the first year of life. Already by the end of the first year the stunting of the growth of the incisors, canines and first molars of the second dentition has taken place, and the dentine is by this time either exposed along the biting edges of these teeth, or is very incompletely covered by a thin layer of imperfect enamel. The germs of these teeth lie deep in the jaws of the infant, and naturally loss of function can play no part.

The malformation of the maxillæ occurs later, it is true, and it is conceivable that the child who subsists entirely on pap food, and does not use the muscles of mastication, will naturally tend to have poorly-developed jaws. But I do not believe this plays any important part in the collapse of the upper jaw, leading to the projection of the central incisors and the overcrowding of the lateral incisors and canines. Rather I attribute these conditions to the softening of the bones, and the muscular debility which are such prominent features of rickets. Nor would it be desirable, if we could, to return to a primitive diet. Even as late as the seventeenth and eighteenth centuries the teeth were used to masticate food for which they were never adapted by nature. Not only were the molars used for grinding, but even the incisors and canines are quite commonly ground down flat at an early age, so that the pulp cavities are exposed. True, the dental arches are, as a rule, well formed, and the palate is low and broad, but this is due to the absence of rickets in the first two years of life, and not to the unnatural work which these teeth were made to perform in later years.

It is important, then, to note that irregularity of the teeth, the tendency to decay and hypoplasia associated with a narrow and high-arched palate and an altered bite, are all conditions which only became common within comparatively recent times. They are the usual conditions associated with

rickets. The condition of the teeth and jaws described by Sir Arthur Keith as characteristic of Neolithic man extended right up to and beyond mediæval times, and is indeed a striking feature of skulls right up to Reformation times and later. Somewhere about the beginning of the seventeenth century a profound change began to take place in the development of the people in England which has left its mark in the growth of the skeleton, but more particularly in the bones of the skull. The contracted dental arch and high-vaulted palate, with marked irregularity and early decay of the teeth, the occurrence of hypoplasia and the tendency to the production of a long-faced lantern-jawed type of individual with a contracted lower jaw, are characteristics very common in the skulls of to-day, and probably date back not further than the end of the sixteenth or the beginning of the seventeenth century. This type is frequently associated with the long narrow-chested development and the sloping shoulders and arched back so often seen in the modern town dweller. The stature of the long barrow men of the Neolithic period is given as 5 feet 5½ inches, while that of the round barrow men of the Bronze Age, which succeeded the Neolithic, is 5 feet 7¼ inches. The difference cannot be attributed wholly to better conditions of life and feeding in the Bronze period, though these had undoubtedly advanced enormously. The two types are probably of a different race, for the long barrow men belong to a long-headed or dolico-cephalic type, while those of the round barrows are short-headed or brachy-cephalic, and the difference in stature may have been partly racial, though in all probability it was also largely a question of improved feeding and environment. A fairly reliable criterion as to the conditions during these two periods can be found in the relative stature of the men and women. Thurnham calculated that the average age of the Neolithic people whose skeletons he examined was not more than forty-five. The average height of the men was about 5 feet 6 inches and of the women only 4 feet 10 inches. The difference between the sexes in civilised communities is only about half as much.

This marked difference of stature bears testimony to the severe struggle for food, for in savage races, in times of famine and stress, the woman fares worse than the man. Besides, early child-bearing retards her growth, while the labour of the community falls largely to her lot. In the Bronze Age which followed the Neolithic period, conditions were more favourable to longevity and the position of the woman was probably improved. Not only was the disparity in stature between men and women much less, but Thurnham finds the average life of the round barrow people whose skeletons he examined was fifty-five.* Enquiry into the life of Neolithic man may appear at first remote from the subject of rickets. In reality it is most apposite. The evidence we have points fairly clearly to the absence of this disease from those early people while their life was a stern, continuous struggle for the means of subsistence. Nor must it be thought that the Neolithic period is wholly a thing of the past. At the present day most of the conditions of life in Neolithic Europe are reproduced at some part of the globe's surface. Thus, as Sir John Lubbock (afterwards Lord Avebury) points out,† the communities of the Stone Age who gave rise to the kitchen-middens (Kjökkenmöddinger) of the Danish coast lived much the same life as the inhabitants of Tierra del Fuego do to-day. These great heaps consist of shells, chiefly oyster shells, and have accumulated on the sites of these early Neolithic settlements. In these heaps, flint implements, bows and fragments of pottery are found. The dog was the only domesticated animal and the other bones found in the heaps are the product of the chase, the stag, roedeer and wild deer. They had no knowledge of agriculture, and though wild berries and nuts would help to eke out the scanty fare in times of famine, their lives must have been associated with frequent periods of great privation and stress. As with all native and savage races, the supply of fat was a great difficulty, and the frequency with

* *Nature*, November 22nd, 1894, p. 92.

† "Prehistoric Times," by the Right Hon. Sir John Lubbock, London, 1890.

which the long bones are split for the extraction of the marrow shows with what care they made use of every available source of supply. In the same way, the life of the Neolithic lake-dwellers in Switzerland is reproduced in the existing pile-villages of New Guinea and other Asiatic islands. These Swiss lake-dwellers had some rude ideas of agriculture and made use of cereals, and they had probably domesticated several animals besides the dog. Great Britain at the beginning of the Neolithic period had become an island, separated from the Continent. The climate was temperate and rather moist. Under favourable conditions, even at this early period, men had learned to tame animals and to use them for domestic purposes; they cultivated wheat and textile plants and used the bow. It is important to remember that even as late as the middle of the eighteenth century one-third of the habitable globe had not advanced beyond the Stone Age period. Rickets did not exist amongst Neolithic people, nor does it exist amongst native races living under native conditions to-day. In South Africa the natives have been intimately associated with European races ever since the surgeon, Jan van Riebeeck, first landed in Table Bay with his expedition in 1652, and cannot now be said to be living under native conditions. Even so, neither in the larger towns nor on the veldt in South Africa have they developed rickets. In America, on the other hand, rickets is so prevalent amongst the negroes of New York and Chicago that it is stated that practically every child suffers from it, many of them severely.

The natives of India, though they live habitually near the border line of want and are subject to recurring devastating famines, widespread and most destructive to human life, do not develop rickets.

It has been shown that the life of primitive peoples is only reconstructed with difficulty, but even when we get to historical times it is exceedingly difficult to find the material which will provide data for a picture of the manner in which the common people lived.

The Roman historians give only occasional scraps of information concerning the social life of the races whom

they conquered. At the time of the Roman occupation the population of England dwelt apart in many separate tribes, and hunting and inter-tribal warfare were their chief occupations. "Their whole life," says Cæsar, "is composed of hunting expeditions and military pursuits: from early boyhood they are zealous for toil and hardship. For agriculture they have no zeal and the greater part of their food consists of milk, cheese and flesh." * Probably the masses were in a state of semi-serfdom and political power lay in the hands of the chiefs and the druids. In the south-eastern part of England life was probably more stable and the country was comparatively prosperous. In 54 B.C. Cæsar, as he marched through the country, was struck with the density of the population in Kent and their apparent wealth. "The population," he wrote, "is immense: homesteads closely resembling those of the Gauls, are met with at every turn; and cattle are very numerous."† They fed on a little bread ground from corn in a hand-quern and on a great deal of flesh meat, boiled or roasted on the ashes or on spits. Their houses were mean habitations constructed chiefly of wooden planks and of reeds or wicker-work covered with a heavy thatch of straw, and as Strabo, the geographer, says, were circular in form.‡ They had one opening for the door on the sunny or sheltered side and a central hearth.

Such were the huts in which Poseidonius was made welcome when he travelled in Gaul. Describing their customs he asserts that, like beasts of prey, they took up whole joints, biting off portions, and if any part were too difficult to be torn off by the teeth, they cut it off with a small knife which, sheathed in a case, lay beside them.§ In the fourth and fifth centuries, when Rome had been compelled to withdraw her troops from Britain to guard her Empire from the barbarians who assailed her frontiers, evil times fell upon the

* "De Bello Gallico," Book VI., pp. 21, 22. Vita omnis in venationibus atque in studiis rei militaris consistet: ab parvulis labori ac duritiæ student. Agriculturæ non student, majorque pars victus eorum in lacte, caseo, carne consistet.

† "Hominum infinita multitudo creberrimaque ædifica fere Gallicis consimilia, pecoris magnus numerus," B.G., V., 12, par. 3.

‡ "Strabo," lib. IV., c. 4, par. 3.

§ "Poseidonius, apud Athenæus," lib. IV., p. 152.

Briton when the hand of the master was removed. For a century and a half darkness falls on the history of the country, and it is not till the latter half of the fifth and the first half of the sixth century that history again emerges, when we find the country in the hands of the true English of to-day, who are mostly descended from the conquering Angles and Saxons. The Anglo-Saxons came not, like the Romans, to administer a new country, but were bent on a purely destructive work. They swept away everything before them and replaced the old civilisation of Britain by a new social organisation of their own. These invaders could not brook the life of towns—they were fitted only for an open-air life in the country where each man owned his house with a small piece of land surrounding it, while the country around belonged to the community. The Roman settlements which they attacked and destroyed they did not inhabit, and indeed even such considerable towns as Canterbury, and Bath, and London itself, seem to have been deserted for a time, and were left to crumble away.*

In "*Crania Brittanica*," published in 1865, Davis and Thurnham give the results of the examination of a large number of skulls taken from ancient British barrows and from burial grounds dating from Roman and early English times. Drawing their conclusions the authors state: "It may be observed that we have met with comparatively few instances of disease among the bones of the ancient Britons. The probability is that diseases of the bones are not common. No morbid appearances such as would be the result of syphilis have presented themselves to our notice." † In an examination of the beautiful series of reproductions of Roman and early English skulls in "*Crania Brittanica*," one of the most remarkable features is the excellent state of preservation of the teeth. The hard palate and dental arches are roomy and well formed, and the teeth are mostly all present. They show evidence of rough usage. They are much worn down and are ground flat so that even the incisors and canines have lost their biting edge. Sometimes

* "*A History of England*," by Charles Oman, Chapter II.

† "*Crania Brittanica*," by Davis and Thurnham, 1865, p. 233.

the pulp cavities are exposed in the grinding process, but there is little, if any, evidence of decay. The well-marked bony development of the jaws, the excellent preservation of the teeth and the freedom from decay all bear definite testimony to the absence of rickets amongst these peoples. The evidence is scanty, but is written on an enduring record—the bones and teeth—and forms a reliable testimony that rickets was not a disease which prevailed during that long period if it existed at all.

Much interest attaches to the recently discovered Rhodesian skull from the fact that the teeth of the upper jaw present appearances resembling true caries. This skull exhibits the usual characteristics of primitive skulls in the great, wide, roomy, flat palate, while the teeth are set regularly in a generous sweep. The teeth are large and well formed, and are considerably ground down, and there is a well-marked formation of secondary dentine. On the adjacent part of the left lateral incisor and the left canine there is an area on each tooth which strongly suggests caries during life. This is quite unusual in early primitive skulls, though signs of abscesses at the roots of the molars, which are present in this skull, are by no means uncommon. Part of the second left molar has been eroded, but this is much more suggestive of disintegration occurring during the long period in which the skull has lain hidden than of caries during life. Even should the decay of the front teeth prove to be true caries, this need occasion no surprise, and would but serve to emphasise the fact that in ancient and primitive skulls such a condition is exceedingly rare. There is certainly no suggestion of the rachitic state in the enormous facial bones of the Rhodesian skull. The tibia and femur found with it are peculiarly slight and gracile, the former bone being straight and well formed, while the portions of the femur suffice to show that there was no increase in the natural curve of the bone.

The study of anthropology is peculiarly helpful in the elucidation of many problems of developmental disease, for normal processes of growth in one organism may appear as pathological variations in another, and may arise in response to altered and perverted environment.

CHAPTER XXIII

Economic Factors in Relation to Rickets from the Roman Occupation to the Close of the Eighteenth Century

THROUGHOUT England there is an interesting record, of which not much notice has been taken, of the physical condition of the English people in past centuries, to be found in numerous collections of bones in different parts of the country. These have been gradually accumulated in charnel houses, and are sometimes in an excellent state of preservation. In pre-Reformation times, churchyards as a rule were small, and to make room for fresh burials the bones of some forgotten occupant had frequently to be removed and were placed reverently in the charnel house—a vault either under or near the church which was built for this purpose. In this way, in the course of generations, churchyards would be dug over time and again, and a gradual accumulation of bones took place. Such a collection is found in the crypt under the church at Hythe. This collection is well-known because it is near a favourite seaside resort not far from London. But it in no way differs in its origin from other collections throughout the country. Usually, local tradition cherishes the conceit that some great battle has been fought in the neighbourhood or that a holocaust has taken place as the result of plague. At Hythe, various skulls are shown with injuries presumed to have been caused in battle, but examination has proved that the spade and mattock of the sexton, long after death, have in most cases been the cause of the injury.* These injuries from much handling

* "Notes on the Crypt and Bones of Hythe Church," by the Rev. H. D. Dale, Vicar of Hythe, and F. G. Parsons, F.R.C.S., Professor of Anatomy in the University of London, Hythe, Kent, 1917.

often become smooth and polished and resemble very closely healed injuries. The history of the collection at Hythe shows that the bones have been under the church since the year A.D. 1600 and were probably placed there much earlier. At least four thousand people—men, women and children—are represented. The death rate of Hythe considering the population could not, for several centuries, have accounted for more than forty burials yearly. It is probable that these bones were dug up during the fourteenth, fifteenth and sixteenth centuries, possibly as early as the thirteenth century, and the stack was completed during the sixteenth century. The bones are in an excellent state of preservation and many of the pathological changes are still well marked. Osteoarthritis of a severe type is common, and the inhabitants of Hythe must have suffered greatly from this condition. About twelve cases show well-marked syphilitic lesions of bone, caries of the spine is to be seen, and union of fractures of the long bones in faulty position is present in several cases. But there is no evidence of rickets. Speaking of this collection, Mr. Parsons says: "I have seen the rickety tibia noted by Dr. Knox, but apart from that I have come across no evidence of the disease which I could recognise." * An examination of the teeth shows the usual characteristics which are associated with prehistoric, early English, and mediæval skulls. The palatal and dental arches are well formed, comparatively few teeth are lost, and caries is conspicuously absent. The teeth are ground down flat and are much worn away, but they are not decayed. Such a condition one might imagine would go with a robust healthy constitution, but enquiry shows that the physique of the people to whom these bones belonged was much inferior to that of the inhabitants of Hythe at the present day. Mr. Parsons † found that the stature of the men averaged 5 feet 5½ inches, while that of the women was only 5 feet 1 inch. The interesting fact is brought out that with a life of great

* "Report on the Hythe Crania," by F. S. Parsons, *Journal of the Royal Anthropological Institute*, Vol. XXXVIII., 1908.

† *Loc. cit.*

hardship, with a coarse and frequently insufficient diet, producing defective growth and nutrition, these people were free from rickets, while to-day, though the people are much better fed and of better physique, rickets is found to be prevalent at Hythe. The state of the teeth is identical with those in another collection of skulls found under St. Peter's Church at Dover, a collection which dates from the thirteenth and fourteenth centuries.

At Rothwell, near Kettering, in Northamptonshire, there is a collection considerably larger than that at Hythe. The vault was discovered two hundred years ago, and from five thousand to six thousand individuals are represented. The bones are not so well preserved as those at Hythe, and thus the pathological conditions in the bones are masked. The physique of those people was evidently under the present-day standard—the women average 5 feet 2 inches in height, but the teeth show the usual characteristics of being ground down and free from decay.* Speaking of the teeth found in these mediæval collections, Mr. Parsons† makes the interesting observation that they form a marked contrast with the skulls which he examined from a disused churchyard under the site of the Bluecoat School in Newgate Street. These belonged to Londoners of the seventeenth century, and not only were the teeth found to be much less ground down, but caries was much more common; that is, already in the seventeenth century the teeth of the Londoner resembled those of the population at the present day.

In the Royal College of Surgeons there is a series of skulls and long bones taken from Clare Market which show an interesting transitional type. In all probability these skeletons belong mostly to the eighteenth century, though some were added as late as the first half of the nineteenth century. Out of 117 skulls examined, 34 may be said to have a contracted and high palatal arch, the arch in the remainder being either moderate or wide, approaching to

* "Report on Rothwell Crania," by F. E. Parsons, *Journal of Royal Anthropological Institute*, Vol. XL., 1910.

† "Report on the Hythe Crania," *loc. cit.*

the native type. The teeth were, on the whole, better than those of the modern Londoner, that is to say, decay was not so frequent. In many cases these teeth were of a transitional type, between the mediæval ground-down teeth without much evidence of decay, and the modern type where the teeth were not ground down but were frequently decayed. The tendency to overcrowding and irregularity of the teeth, owing to malformation of the dental arch, was noted in several cases. These skulls differed markedly from those of the Hythe collection. In the Hythe skulls the jaws gave an impression of strength. The dental arches and the palate were wide and well formed, the teeth were regular and met without overlapping, and, though much ground down, there were comparatively few absent and decay was quite uncommon. In the Clare Market skulls the teeth were frequently decayed and sometimes irregular. The dental arches tended to be much more contracted, and the palate was frequently high and arched instead of being flat and roomy as in the Hythe skulls. In at least ten of the long bones belonging to the Clare Market skeletons rickets was well marked; syphilitic osteitis and ulceration of the bones and osteo-arthritis were present in several cases.

In a recent study of a series of bones found in Whitechapel and Liverpool Street, belonging in all probability to seventeenth century plague pits, Professor Karl Pearson and Miss Julia Ball, speaking of the femur alone, found that out of seven hundred Whitechapel femora, ten showed evidence of probable rachitic changes, whilst out of 217 Liverpool Street femora, three showed a similar condition.* Speaking of the stature of the Londoner, Professor Pearson makes the interesting comment that the seventeenth century Londoners were distinctly shorter than the nineteenth century commonalty, and proposes the problem whether migration, nutrition, or natural selection accounts for the

* "A Study of the Long Bones of the English Skeleton," by Karl Pearson, F.R.S., and Julia Ball, M.A.

difference. Evidence is brought forward to show that the modern British femur differs from that of the seventeenth century Londoner in being a larger but, at the same time, a more gracile bone.

Two factors are of considerable importance in considering these differences, namely, the quality of the feeding and the housing conditions.

There has been considerable improvement in the quality and quantity of the food supply ; within modern times cases of extreme want and deaths from starvation are rare. A large proportion of the population in the East End of London, however, still lives on foods which are deficient all round in the various constituents necessary for the support of vigorous health and growth. Notably there is a deficiency in proteids and fats. For this reason, in children suffering from malnutrition, the addition of one tablespoonful of cod-liver oil to the diet, as is commonly done, has not nearly the same beneficial action as the addition of a pint of milk, which makes good the deficiency of all the constituents necessary to a proper diet.

Among the Jewish population in the East End of London there is no want of fat in the diet. The general nutrition of these children is excellent, but the incidence of rickets is about the same as amongst the non-Jewish section of the community. Their good nutrition modifies the severity of the disease, but does not diminish the frequency with which the children are attacked. In other words, there is some other factor than the food factor responsible for the disease, and this is to be found in the very defective housing conditions under which both the Jewish and the non-Jewish sections of the community live. Housing conditions have improved in the town populations generally, but only to a limited extent. Effective sanitation, it is true, has banished many diseases, but over-crowding of families in one, two, or three rooms, deficient in light and ventilation and the means of exercise, is still very common, and, indeed, tends to become exaggerated as the population increases in density. This faulty environment

still has a profound effect on the growth of the infant and the young child. The improvement which has taken place in the national stature is probably to be attributed to improved feeding, but with this increase in growth, though there has been a modification in the type of rickets, the malady is probably more frequent and more widely spread to-day than it has ever been in the past.

Overcrowding is a relative term, and, while, with a population of thirty-three millions in England and Wales, it can readily be understood how slum areas arise, it is not so readily comprehended that in Queen Elizabeth's time, with a population of three and half millions, similar influences were already at work or were beginning to make their appearance. The essential and constant factors producing the exceedingly wide diffusion of rickets at present found in Europe and in North America within the temperate zone are the enormously rapid growth of population within the short space of three hundred years, and the concentration of this population into huge industrial areas. It cannot be too frequently reiterated that rickets is a disease of early infancy, and in studying the conditions which produce it, the first place must be given to those factors which act most intensely on the young infant.

It is obvious that under the conditions of life up to Elizabethan times, with a sparse population almost entirely dependent on agriculture, an infant was brought up in an entirely different environment from that which surrounded the child born in a basement cellar in Manchester, or Liverpool, or in a crowded slum area in the East End of London to-day. In the first case the child frequently lived, it is true, in a mean hut or hovel devoid of comfort, but such hardships do not breed rickets. The life of the whole community was regulated by the sun, and the greater part of the day was spent in arduous toil in the open. At as early a date as possible the young infant shared in the open-air life of the community, and accompanied the mother in her varied activities. In a disease centre such as Manchester or the East End of London the child may hardly move from one

close, confined, sunless room for weeks or months during the inclement winter.

A study of the economic factors which bear on the production of great cities and modern housing conditions has an important bearing on the ætiology of rickets. Even in Queen Elizabeth's time these conditions were beginning to come into evidence, though the true development of modern conditions did not occur till a much later period, being associated with the development of modern industries, notably the cotton industry.

Already, in Queen Elizabeth's time, a complex problem had arisen in the number of idle and indigent poor, for whom no provision was made. The passage from manorial rights, with the disappearance of the last traces of serfdom, which was only completed in the sixteenth century, was not altogether to the advantage of the agricultural labourer. It threw a large number on the labour market at a time when the demand for labour was limited. Industrial capital hardly existed in England in the fifteenth century, in the sense of ready money for wages used by an employing class who held the command of capital and used it in industrial pursuits. At the same time a growth of capital in agriculture began which tended to convert much of the agricultural land into grazing for sheep. These enclosures, with their accompanying evictions, produced a struggle between the small farmer working his holding and the large holder who had a sheep farm. These two classes, the disbanded retainers who belonged to the old serf class, who had not yet been able to find a market for their labour, and the evicted agricultural worker who had been rendered homeless, formed themselves into vagrant robber bands who rapidly became a terror to the community.

In 1601 the celebrated Poor Law of Queen Elizabeth came into force whereby it was provided that the able-bodied vagrant should be made to work or, in default, go to prison, but those who, through age or sickness, were unable to work, had to be supported from rates levied on the parish

to which the vagrant belonged. The enactment against the sturdy rogue is important as showing that it was not only the distressing amount of poverty which produced the measure, but the desire of the community to protect itself against the lawless bands who were infesting the country, making the roads unsafe, and property and even life itself insecure. For a time the position was greatly eased. Colonial enterprise and increase of trade had added immensely to the wealth of the nation, and had helped to settle many grave social problems which had arisen. But it is to be noted, that this increase of wealth mostly benefited town populations and did not affect the rural populations in anything like the same degree. Work was found in towns for a large number of unemployed.

It is from the time of Queen Elizabeth that the growth in importance of the urban population as against the rural must be reckoned. This is a factor in England of ever increasing importance, and has a very direct bearing on the enquiry into the cause of rickets. The end of the sixteenth and the beginning of the seventeenth centuries formed a period of comparative prosperity throughout the country. The rural population had not actually outgrown the needs of the agricultural community; indeed, the farmers called out for labour. The increased wealth of the towns, with the development of trade generally, had largely increased the demand for artisans, who were relatively well paid, and had drawn on the class who were likely to become vagrants and robbers and a menace to the security of the community. But in the seventeenth century changes were rapidly occurring. The population of England had increased in the second half of the seventeenth century to five millions, and the increase was greater in the northern than in the southern shires. It is computed that four-fifths of the common people were employed in agriculture.* Agriculture was England's chief industry, and, in the "Working Life of Women in the Seventeenth Century," Miss Alice

* Macaulay's "History of England," "State of England in 1685."

Clark divides the agricultural community into three classes *: (a) farmers who had sufficient land for the complete maintenance of the family; (b) husbandmen whose holdings were only able to maintain the family in part, and who had to supplement by working for wages; (c) wage-earners who had no land and depended completely on their wages. The wage of the agricultural labourer was exceedingly low, about 3s. 6d. per week. On such a wage it was admittedly impossible for the head of a house to support a wife and family, for, even under the system of poor relief, 4s. to 5s. a week was considered necessary for an adult's maintenance. The wage was intended to be merely supplementary while the family earned their food from the croft. It had always been the policy of Government administration under the Tudors to support the responsible yeoman and not to encourage the wage-earner, who, instead of becoming a defender of his country, was ever likely to become a burden on his parish.

The wages were not regulated by the law of supply and demand but were regulated by the magistrates at Quarter Sessions, and the wage was, in the first instance, purposely made small so that the labourer would be dependent on the farmer for payment in kind in foodstuffs. Food on the farms was relatively abundant. At no time was the farmer independent of the labourer. Means of transport were exceedingly limited, so that each district depended on its own supply of corn. At harvest time the whole community, men, women and children, was employed in the fields, and, directly or indirectly, much of the food of the rural population came from the farms. When the labourer had an allotment, the woman of the house and the children worked out of doors, cultivating the garden, and tending pigs and cows, while the husband worked on the neighbouring farm. Where there was no allotment, the woman's time would be employed in spinning and making cloth, for the clothing of the household was made at home and not purchased. The life was of

* "Working Life of Women in the Seventeenth Century," Alice Clark, 1919.

the hardest, and, in the case of the labourer without land, he was ever working on the borderline of starvation. But probably too gloomy a view is taken of the life of the labourer in the seventeenth century. Information is but scanty as regards the conditions of the common people and has been mostly derived from the records of poor relief and of the magistrates' courts at Quarter Sessions. These records do not tend to give the enquirer a natural perspective. Sir Wm. Temple, one of the most astute politicians of the time, and one who had travelled much, states, in the work published by Swift after his death, "An Essay upon Health and Long Life," "I have heard and very credibly, of many in my life above a hundred years old, but have observed most of them to have been of Derbyshire, Staffordshire or Yorkshire, and none above the rank of common farmers. Health and long life are usually blessings of the poor, not of the rich, and the fruits of temperance rather than of luxury. And, indeed, if a rich man does not live like the poor, he will certainly be the worse for his riches." *

The same rapid spread of rickets which occurred in the seventeenth century in England can be watched going on in new countries to-day. Rickets is not a disease indigenous to America, but has developed rapidly in the United States in proportion as the towns have grown in size and density and industrial conditions have developed. Negro races, like all native races, tend to occupy the worst parts of the large towns, and so common is rickets amongst them in New York, that one hardly sees a negro child without some evidence of the disease. In Australia, till comparatively recently, the disease was unknown, but is becoming more common for the same reason.

The disease has lasted for so many generations, and has been so prevalent a scourge throughout Europe, that it is difficult to realise that a population free from it is a possibility, and that rickets comes within the class of preventable

* "Miscellanea," the Third Part, Essay II.—"An Essay upon Health and Long Life," published by Jonathan Swift, A.M., Prebendary of St. Patrick's, Dublin. London, 1701.

diseases, just as it is hard to believe that a town can exist without slums or a successful industry without inflicting hardship on the workers who contribute to its success.

The seventeenth and eighteenth centuries saw the strange anomaly of huge industries rising and developing with great rapidity and producing enormous wealth, while, at the same time, the workers who were engaged in producing this wealth were becoming relatively poorer and the conditions of their lives more and more miserable, and, finally, unbearable, culminating in the industrial revolution at the end of the eighteenth and the beginning of the nineteenth centuries.

In the seventeenth century, the growth of towns and industry were on a comparatively small scale when compared with present-day conditions. But the process had already made considerable progress and much misery existed. At the time of the Domesday Book, 1086, there were hardly any towns.

Speaking of the progress of population in England, Rogers * maintains that during the fourteenth, fifteenth and sixteenth centuries the population remained almost stationary and amounted to about two and a half millions. At the close of the fourteenth century, England and Wales together had a population of under two and a quarter millions, while the following was the population of the chief towns :—

London	...	...	...	35,000	inhabitants.
York	...	...	...	11,000	„
Bristol	...	...	...	9,500	„
Coventry	...	...	...	7,000	„
Norwich	...	...	...	6,000	„
Lincoln	...	...	...	5,000	„

No other town had over five thousand inhabitants. Nine-tenths of the population were employed in agriculture. Kent had for long been a prosperous county. Cæsar's surprise at its wealth and density of population has already

* "The Industrial and Commercial History of England," by James E. Thorold Rogers, Professor of Political Economy in the University of Oxford, and of Economic Science and Statistics, King's College, London. London, 1905.

been noted. In the first half of the sixteenth century, the population in nine Kentish hundreds on the eastern side of the county was 14,813, and had remained so for two centuries. It was still prosperous and has remained so to this day. In these hundreds there were no large towns and there are none now, though the population in 1861 was 80,080—that is, six times as much as it was three centuries before. Up to the sixteenth century, with a population of two and a quarter millions for England and Wales, the conditions for the development of rickets did not exist. But the conditions of life of the people were rapidly changing. “I have been convinced,” says Rogers, “that no material increase of the English population took place during the last half of the sixteenth century. Now it is certain that at the end of the seventeenth century the population is more than double that which I have calculated was in England at the close of the sixteenth century.” These figures agree with Macaulay’s estimate of five millions during the second half of the seventeenth century. This increase in population was partly due to improvement in agricultural methods and increased production, but was mainly due to the fact that weaving—especially woollen weaving—was developing rapidly in the north of England. The anonymous author of “The Interest of Scotland,” writing in 1732, speaks of the growth of woollen manufactures in Yorkshire, and of linen and of similar fabrics in Lancashire.

As has already been seen, industrial capital hardly existed in the fifteenth century, and it was not till the time of Queen Elizabeth that the urban population began to rival the rural population in importance. From this time began the growth of industrial centres. London in 1685 had half a million of inhabitants and had been for half a century the most populous capital in Europe. In the reign of Charles II. (1660–1685) no provincial town in the kingdom contained thirty thousand inhabitants, and only four contained so many as ten thousand. Small though these numbers are, they show even at this date a tendency to the formation of industrial centres. Bristol, the first English

seaport, contained twenty-nine thousand inhabitants; Norwich, the first English manufacturing town and the centre of the cloth industry, about the same number. York, the capital of the north, and Exeter, the capital of the west, each had about ten thousand inhabitants, Worcester and Nottingham about eight thousand, and Manchester had under six thousand people. Leeds was already the centre of the woollen manufactures of Yorkshire and contained about seven thousand souls. In the City of London, after the Great Fire, houses of better quality were built and brick was used, but elsewhere, houses were made of wood covered with thatch. Sheffield in the seventeenth century was the little capital of a district familiarly known as Hallamshire.

In 1554 the inhabitants of Sheffield represented to the Queen that the fourteen hamlets within the parish were never devoid of plague and other evil diseases, which they attribute to the great number of poor and impotent persons inhabiting them. A realistic description of the life is given in a survey of the town of Sheffield made January 2nd, 1615, by twenty-four of the most sufficient inhabitants.* The report states: "there are in the town of Sheffield 2207 people: of which there are 725 who are not able to live without the charity of their neighbours. These are all begging poor: 100 householders which relieve others, though the best sort are but poor artificers: 160 householders, not able to relieve others. These are such (though they beg not) as are not able to abide the storm of one fortnight's sickness but would thereby be driven to begging: 1222 children and servants of said householders the greatest part of which are constrained to work sore to provide them necessaries." In 1685 the population had increased to four thousand. For long the chief industry had been the manufacture of whittles or coarse butcher's knives. The severe labour required in some departments of the Sheffield manufactures is said to have occasioned an unusual number of distorted limbs.

* "Hallamshire," by Joseph Hunter, 1819.

The chief industries in England in the seventeenth century were the textile industries. These were : (1) woollen ; (2) linen ; (3) miscellaneous, such as silk. The cotton industry with its factory system was not organised on a large scale till the following century, and was the chief factor which led to the industrial revolution at the close of the eighteenth century. For long, weaving had been carried on at home by the woman of the house for the manufacture of the clothes of the family.

In the second half of the seventeenth century the increase in the population and the growth of textile industries complicated matters, and not only encouraged the growth of industrial centres, but established the system of the hired labourer paid entirely by a wage which was the whole support of himself and his family. The wage-earner who was dependent solely on his wages suffered great hardship. Three shillings and sixpence to four shillings a week was the wage of an agricultural labourer ; workmen employed in manufactures had higher wages, up to 1s. per day, though they were often compelled to work for less. The low wage which had sufficed for the agricultural labourer in earlier times, and which had been considered merely supplementary, now formed the basis in calculating a man's earning capacity.

To make it possible to live, the woman of the house had to work under conditions which ignored her rights as the mother of children. Child labour prevailed in the seventeenth century to an extent which—compared with the extent of the manufacturing system—seems almost incredible. At Norwich, the chief seat of the clothing industry, a little child of six years old was thought fit for labour, and even philanthropists of that time mention with exultation that in that single city, boys and girls of very tender age created wealth, exceeding what was necessary for their own subsistence, of £12,000 a year. The bricklayer, mason and carpenter were equally poorly paid. Writing about 1840, Macaulay in his history states : " It seems clear that the wages of labour, estimated in money, were, in 1685, not more than half of what they now are ; and there were few

articles important to the working man of which the price was not, in 1685, more than half of what it now is."

Beer was cheap and abundant. Meat was also cheap, but was still too dear for the labourer to buy from his small earnings. By the great majority of the common people of England it was partaken of only once or twice a week. Pork was more common, and had indeed from very early times and for many centuries throughout Europe been the only animal food in general use.

Bread was made from wheat flour, was coarser than it is now and was too dear for general use, and the great majority of the common people lived on rye, barley and oats.*

Food was abundant in England, and in towns such as London and Bristol merchants were noted for their rich hospitality and the excellence of their tables both as regards foodstuffs and excellent wines. The inns of England were famous throughout Europe for their liberal entertainment, and wines and good food were obtainable even in small village inns at a moderate charge. In the seventeenth century, England abounded with well-conducted inns of every rank.

But this was no help to the labourer, and in the industrial centres he had great difficulty—even by continuous and assiduous toil—in earning enough money to buy sufficient wholesome food for the sustenance of himself and his family.

The rise of the textile industries was the beginning of industrialism as we now understand it. The wages were continued on the basis set by the wage of the agricultural

* The following is a chart of the children's diet in Christ Church Hospital in the year 1704 :—

For breakfast	...	Bread and beer.
For dinner	...	Sunday, Tuesday, Thursday, boiled beef and pottage. Monday, milk pottage. Wednesday, furmity or frumenty (hulled wheat boiled in milk and seasoned with cinnamon, sugar, etc.). Friday, old pease and pottage. Saturday, water gruel.
For supper	...	Bread and cheese, or butter for those who cannot eat cheese.
Sunday supper	...	Legs of mutton. Wednesday and Friday, pudding pies.

labourer, but obviously without the chance of free food. Throughout the country it was becoming increasingly difficult to obtain adequate housing accommodation. But one of the worst features of the textile industries was that it employed women and children very largely. Norwich and Norfolk generally formed, as has been seen, an important centre of the wool industry in the seventeenth century. It is computed that about eight women and children were employed to one man. To eke out the small wage of the father the wife made the clothes for the family at home and also earned a little by her spinning. At as early an age as possible the children were set to work, and even in such a heavy industry as the iron industry at Sheffield young children were employed with the most disastrous results. The evil influences which had already begun to sap the health of the common people in the seventeenth century may be classed under three heads : (1) slum dwellings and overcrowding, with all that this implies in defective hygiene, loss of sunshine and fresh air and want of exercise, especially in the first two years of the life of the growing infant ; (2) excessive labour on the part of the mother and children, who had also to work continuously to eke out the small wage of the father ; (3) deficient and defective feeding.

These conditions are exceedingly complex, and the fact that they usually present themselves in combination renders it necessary to examine each in very great detail before deciding on any one factor as the actual cause of the disease. In the Middle Ages the conditions of life were in many communities very severe ; houses were huts and hovels devoid of comfort, but had this virtue that they encouraged life out of doors, for not much comfort was to be found indoors. Food was rough and coarse and was often scanty, but rickets was absent, for no matter what the diet the disease does not develop when the life is regulated by the sun and is spent in the open. It might be argued that the very coarseness and roughness of the food would at least mean that the accessory food factors were present in adequate quantity and so inhibited the disease. Ample reasons exist for considering

such a view untenable. The inadequacy of the diet in these early times led to dwarfing of the individual when compared with present-day standards. Later in the seventeenth century rickets became prevalent throughout all classes and was noted as specially frequent and severe amongst the children of the wealthy and in association with luxury. Excess of rich feeding and the confinement of the young infant for months in succession in warm, stifling, and badly ventilated rooms were the conditions which were present, and were the factors blamed by all contemporary observers of note for the production of the disease; the confinement ended then, as it does now, in the production of rickets. The conditions reproduced in such a nursery were those which exist in our slum areas to-day, where families are herded together during the winter months in one or two rooms.

Among the poor in early times, when life was much in the open, scanty and insufficient diet was incapable of producing the disease. Among the rich in the seventeenth century adequate and wholesome diet could not protect the child from the onset of the disease in its severest form when the infant was kept indoors in a vitiated and debilitating atmosphere. In the seventeenth and eighteenth centuries among the poor in large centres where the food was insufficient in quantity and poor in quality, and the worst features of slum dwellings were present in ever increasing measure, the disease became a national evil, which had far-reaching and disastrous effects on the health of the whole community.

It is important to realise the part played by the various factors. Defective feeding and insufficiency of food did not then, and do not now, produce rickets, though they undoubtedly aggravate the condition when present, as they do any other morbid state, especially when it involves malnutrition and failure of development. Deaths from starvation and marasmus in young infants were quite common, and in both these conditions rickets was then, as it is now, conspicuously absent.

Child labour produced marked signs in the rachitic child, but did not produce the disease, which arose then, as now,

almost immediately after birth. The causes of the disease will be discussed more fully later. Suffice it to say now, that the essential causes of the disease lay in the excessively unhygienic conditions in which these infants were reared from birth to the end of the second or third year of life, at a time when fresh air, sunlight, and exercise are more important than at any other period of life.

It has already been noted that at the end of the seventeenth century the population had doubled as compared with what it was at the close of the sixteenth century. During the eighteenth century the population was again nearly doubled. This century saw the rise of the great cotton industry which was to pour wealth into the hands of the manufacturer, while it grudged the pittance of a wage paid to the worker who produced this wealth—a pittance barely sufficient to support himself in the most meagre fashion, and quite inadequate to support himself and his wife in anything like decency or comfort. During the first sixty or seventy years of the eighteenth century the new agriculture produced abundance, wages rose somewhat, and the position was a little easier. But as the population increased towards the close of the century, so it sank deeper and deeper into misery. There is but little doubt that this misery was largely the fault of the legislature, and of such old abuses as the justices' assessments of wages, and of the enclosures and the appropriation of the commons. The extraordinary position was maintained that the worker, whose labour produced the wealth of the country, was at the same time a burden to the community in that his wages did not suffice to maintain himself and his family. In place of raising the wage, the only remedy that suggested itself to the Government was the fatal policy of quartering the workers permanently on the rates under the allowance system. Nowhere was the life of the worker more deplorable than in the large towns of Lancashire and in connection with the cotton industry.

These conditions which arose at this time are the actual conditions which persist to-day, which still have a profound

effect on the physical growth and well-being of the nation. The grosser and more evident evils such as existed in the employment of child labour and of women in these early days have been swept away. Factories are more carefully constructed and are regulated and inspected to ensure that the surroundings of the worker are made as wholesome as possible. Death from starvation is no longer common in our large towns; but the basic evils connected with overcrowding and slum dwellings persist to-day on a larger scale than ever, and blight the growth of the infant from the day of its birth. After the age of three these conditions, though still harmful, press less heavily on the child. From this time onwards the child is allowed the freedom of the streets, but for the first two years it is brought up under conditions entirely inimical to its proper development and growth, at a period when growth is more rapid than at any other time, and when a relatively enormous increase is taking place in the brain and nervous system.

About 1760 the cotton industry began to oust the woollen industry from what is now peculiarly the cotton district. In the earlier days of the cotton industry a considerable number of weavers worked on their own account, owning their own looms, and at the same time held small pieces of land. Specialism, however, rapidly severed this connection. The making of finer and more complicated fabrics could not be suitably combined with farming. But the spirit of the times was centralising management before any mechanical changes of a revolutionary kind had been devised.

Speaking of the end of the eighteenth century and the beginning of the nineteenth century, Butterworth states that in Oldham a large number of weavers possessed spacious loom-shops, where they not only employed journeymen weavers but a considerable proportion of apprentice children. In 1769 Arkwright obtained his first patent for a machine for spinning cotton yarn. Crompton's spinning mule followed in 1775, Cartwright's power loom in 1787, and Eli Whitney's famous gin in 1793. Water power was required to drive Arkwright's machinery, and this tended to cause a decen-

tralisation of the industry. Thus in 1788 there were 143 water mills in the cotton industry of the United Kingdom distributed as follows :—

Lancashire	..	..	..	41
Derbyshire	..	..	..	22
Nottinghamshire..	..	..	..	17
Yorkshire ..	..	..	..	11

while the remainder were scattered throughout Scotland and England. Ultimately, the steam engine, first used in the cotton industry in 1785, drew all branches of the industry into towns and centralised it in the cotton districts proper. The manufactures were entirely taken out of the English cottages and farm-houses.

The sudden development of manufacturing, and the substitution of mere mechanism for the skill of the individual operative, resulted in a demand for cheap child workers. The employment of children soon became general, and large numbers were crowded together in factories before the change had attracted much attention. It began with the apprentice system, children being procured from the workhouses of London, Birmingham and Northern England. Arrangements which would now be considered revolting were often made between the manufacturers and the parish workhouses for bands of children for a number of years, in which the condition of the children was totally disregarded. Such, for example, were the provisions whereby it was agreed that with every twenty sound children, one idiot child should be taken.

A long struggle now began to improve these conditions, but so different was the point of view, that in the first half of the nineteenth century it may be said that every political economist opposed factory legislation, and the manufacturers were unanimous in opposition to any abridgment of the right to employ children. In 1784 the magistrates of Lancashire passed a resolution that apprentices should no longer work in the night or more than ten hours a day. In 1802 Sir Robert Peel secured the passage of a bill abolishing

the apprentice system, while the Act of 1818 is still considered an excellent code for factory legislation. In 1833 an important measure was passed curtailing the abuse of child labour, enforcing some education, and providing for factory inspectors, of whom there were at first only four. The Act of 1844 included women under the term "young persons." The proportion of young persons, women and children, engaged in the cotton industry is so high that most regulations affecting them, for example, those relating to the hours of labour, must practically be extended to all cotton operatives. This Act killed night work, for young persons and children were not allowed to work at night. In 1847 the ten hours Act was passed, and a further reduction of the hours to $56\frac{1}{2}$ was secured in 1874, which was cut down by another hour in 1901.

An exceedingly complex state of affairs had now arisen, the consideration of which is of the first importance in considering the ætiology of rickets, and the measures which are required for its prevention and cure.

Sanitation as understood to-day was non-existent ; food was dear, and the reward of labour was such that the worker lived on the verge of starvation, and at all times his food was insufficient in quantity and poor in quality. The workers lived in jerry-built houses in courts and alleys under conditions which were prejudicial to the health of the parents, and were peculiarly dysgenic in that they bore heavily on the pregnant and nursing mother, and on the young infant. Not only were these conditions inimical to health, but they were contrary to all sense of decency.

The first two factors, sanitation and feeding, improved enormously during the nineteenth century ; the housing question has unfortunately stood still and remains the essential factor which tends to pervert the growth and development of the nation to-day.

CHAPTER XXIV

Conditions Present in Slum Areas which Tend to Produce Rickets. The Conditions in North-East London, with a Statistical Enquiry into the Incidence of Rickets in this Area

THE vile conditions which had been allowed to invade the slum areas of all large towns naturally brought retribution in their train. The state of health of the inhabitants was deplorable, and the mortality, especially the infant mortality, was high. But what alarmed the nation was that these areas formed centres from which epidemics of infective disease spread. It began to be realised that it was not possible to set the slum areas apart, and to treat them as if they did not exist. They forced themselves on the attention of the wealthy by invading their homes. Typhus is a disease peculiarly dependent on overcrowding, want of ventilation, filth, debility, and privation, and epidemics were common up to as late as 1815. Typhoid fever, which was only differentiated from typhus by Jenner in 1850, is clearly traceable in earlier records. Epidemic diarrhoea was a frequent scourge. Want of ventilation and light are conducive to a high mortality from diarrhoea. Among the common conditions which are harmful in this way are narrow, dark courts and streets, obstructive walls or buildings, back to back houses, overcrowding, and neglect of ventilation of rooms.* Smallpox was rife, and had been so for a long period. The "bills of mortality" show that upon the average 7 to 9 per cent. of the persons buried in London during the seventeenth and eighteenth centuries had died from smallpox, and in epidemic years the proportion often rose to 13, 15 or even 18 per cent. During the thirty-one

* "Hygiene and Public Health," by B. Withers Whitelegge. London, 1890.

years 1770-1800, smallpox caused 59,253 out of the 626,530 deaths in London, or 9·4 per cent.

Such were some of the acute conditions which helped to swell the mortality tables, and which drew the attention of the Government to the urgent need for reform. It can readily be understood that in such areas healthy normal growth was and is impossible. Severe and fatal epidemics are sensational episodes in the life-history of a nation, and cannot be ignored. But conditions which blight the mental and physical growth of the people without producing a high mortality have been lightly passed over. It is only since the late war, when an urgent call was made upon the effective manhood of the nation, that it was realised how alarmingly the country fell short of what, under happier conditions, might reasonably have been expected. Nor is the falling off due to gross disease so much as to defective growth and development, an insidious process sapping the very vitality of the nation.

The constant recurrence of typhus and other infective diseases in these slum areas and their frequent spread to the houses of the well-to-do, at length alarmed the nation, and in 1844-1845, a Royal Commission reported on the state of the large towns and populous districts, and the conditions which led to high mortality. Some striking pictures are drawn of the unhappy conditions under which the working class of that time, throughout the whole country, lived and laboured.

Dr. Duncan deals with the conditions met with in Liverpool.* The census of 1841 showed the population to be 223,054, of whom 160,000 belonged to the working class. Large numbers of these lived in courts and cellars. Courts usually consist of two rows of houses facing each other, with an intervening space of from nine to fifteen feet, having from two to six or eight houses in each row. The court communicates with the street by a passage or archway about

* "On the Physical Causes of the High Rate of Mortality in Liverpool," by W. H. Duncan, M.D., 1844, Appendix to First Report of the Commissioners of Inquiry into the State of Large Towns and Populous Districts, 1844.

three feet wide. The further end of the court may be built in by a high wall or may be blocked up by the back or side of an adjoining house. The court forms a cul-de-sac with a narrow opening which prevents the entrance of fresh air and effectually interferes with its circulation. The houses, three stories high, contain three rooms of about ten or eleven feet square, and are usually built back to back, so that no through draught is possible. In 1842 the town council estimated that there were in Liverpool 1,892 courts containing 10,692 houses and 55,534 inhabitants. That is to say, one quarter of the whole parochial population and more than one third of the working classes were resident in courts. It was estimated that there were 6,294 inhabited cellars in Liverpool containing 20,168 inhabitants. These cellars were from ten to twelve feet square, generally flagged, but frequently having only the bare earth for a floor, and were sometimes less than six feet high. There was often no window, so that light and air gained access only by the door. The streets, the report states, in the working-class areas are on an average eight yards wide. Each house is occupied by two or more families exclusive of the cellar, and most of the densely peopled lodging-houses are in the street. There is no place for the disposal of refuse, and Dr. Duncan states that he does not know of a single court in Liverpool which communicated with the street or with a sewer by a covered drain. The soil of the courts and streets became saturated, and contaminated the walls of the cellars in which large numbers of the population lived. Dr. Duncan points out that these conditions contribute to a high mortality : (1) by deteriorating the general health of the inhabitants and rendering them prone to the attacks of nearly all diseases ; (2) by inducing the common fever of the country—typhus fever ; (3) by their effects on the organs of respiration. Before the same Royal Commission, Dr. P. H. Holland gives evidence dealing with the working-class area of Chorlton-upon-Medlock, one of the townships of the borough of Manchester. He divides the streets into three classes, the third being the worst. The houses in each class of street he also

divides into three, the first being of ample size and having yards, lobbies and kitchens and water laid on. These houses exceed £20 a year in rent. The second class of house is the better sort of cottage with a back door, while the third or worst conditioned class has no back door allowing of through ventilation, and there is no yard and no privy and no water laid on. The mortality in the best houses of the first class of streets is 1·9 per cent. per annum, while in the third-class houses of the worst streets it is 4 per cent. per annum. Worked out over a period of five years ending June, 1843, the mortality in the various classes of houses and streets may be shown as follows :—

Classes of Streets.	Classes of Houses.	Computed Population.	Rate of Mortality.
			Per cent.
1	1	5,143	1·95 or 1 in 51
	2	4,350	2·2 „ 1 „ 45
	3	980	2·7 „ 1 „ 36
2	1	1,431	1·8 „ 1 „ 55
	2	5,094	2·6 „ 1 „ 38
	3	2,780	2·8 „ 1 „ 35
3	1	—	—
	2	820	2·8 „ 1 „ 35
	3	4,074	4 „ 1 „ 25

Dr. Holland observes that the worst class are the worst fed, being the poorest, and that the individuals are frequently dissipated and improvident. The poor districts have a higher proportion of children than the wealthier districts. But Dr. Holland, like all the other observers, agrees that it is the housing condition and not want of food which is the cause of the greater mortality and incidence of ill-health. Holland closes by stating: “When we find the rate of mortality four times as high in some streets as in others, and twice as high in whole classes of streets as in other classes, and further find that it is all but invariably high in those streets which are in bad condition, and almost invariably low in those whose condition is good, we cannot

resist the conclusion that multitudes of our fellow-creatures, hundreds of our immediate neighbours, are annually destroyed for want of the most evident precautions."

In 1855, Dr. A. Schoepff Merei, who had practised in Buda Pesth, and who afterwards practised for some years in Manchester, wrote a very valuable book on the subject of rickets.* In both towns he had made a special study of the disease, which was exceedingly common in the Pesth division of Buda Pesth and also in Manchester. He finds it more common in Manchester than in almost any other town in England, and markedly more so than in Liverpool, which is only thirty miles away. He comes to the conclusion that neither climate nor unsuitable diet accounts for the great frequency of its occurrence, though the conditions of life are such that both these factors exert a more powerful influence than they otherwise would, had the housing conditions been less defective. The essential cause of the disease, he believes, is to be found in the vast extent of overcrowded narrow quarters. The air of these vast central quarters of Manchester and Salford, he states, is charged with animal exhalations, and carbon and sulphur vapours from the smoke, and as we pass away from these centres the disease decreases in frequency.

In 1844, Frederick Engels † describes the state of the working class in Manchester, but unfortunately he tends to exaggerate what required no elaboration but only a simple statement to be convincing, and he attempts to deal with the intimate life of the common people, with which, from the nature of things, he could not have been very familiar. But making allowance for this tendency to over-statement, the picture he draws is vivid enough to convince one that it is not far from the truth. Forty to fifty thousand persons are stated to dwell in cellars in Manchester and its suburbs, equal to about 12 per cent. of the working class. The streets are described as filthy and narrow in the slum areas,

* "On the Disorders of Infantile Development and Rickets," by A. Schoepff Merei, London, 1855.

† "Condition of the Working Class in England in 1844," Frederick Engels, London, 1892. First published in Germany in 1845.

with offal lying around everywhere, and swine in the streets feed on decayed vegetables. The streets are badly drained. The houses have no useful windows and no ventilation, and if the windows did open to admit of air from the outside, the air of the streets is also foul and putrid. The clothing of the people is inadequate ; there is very little wool and no linen. The working classes have no property of their own. The dwellings are everywhere badly planned and badly built, and are allowed to fall into disrepair. The inhabitants are confined to the smallest possible space, and at least one family usually sleeps in each room. The food is in general bad, often almost unfit for use, and in many cases, at least at times, it is insufficient in quantity. From the vitiated air of the streets the still more vitiated air of the rooms containing whole families has to be replenished. The cellars are damp and garrets leak, and the unfortunate inmates live in the greatest discomfort. Such are some of the conditions described by Engels as prevailing in Manchester in 1844, and it is not surprising that he notes that the inhabitants are narrow-chested, with pale, sallow complexions. A similar type, he states, is to be met with in London.

D. B. Reid * reports on the northern coal mine district, including Newcastle, Gateshead, North Shields, South Shields, Sunderland, Durham, and Carlisle. He shows that the towns and villages present abundant evidence of the causes of the high rate of mortality. Leading streets may be moderately favourable, but on turning into the lanes and courts and alleys frequented by the poor, the conditions indicate the accumulated influence of evils that must have been progressing over a long period, and augmenting with the increase in density of the population. He finds these habitations for families destitute alike of adequate accommodation for the separation of the sexes, and even of those conveniences which common decency requires ; the absence of a sufficient and easily accessible supply of wholesome water

* " Report on the Northern Coal Mine District," by D. B. Reid, Appendix to Second Report of the Commissioners of Inquiry into the State of Large Towns and Populous Districts, 1845.

and the utter inefficiency of the means resorted to for cleansing, drainage and sewerage, are evils that press heavily upon a large number of the humbler classes in every one of these towns. A vast amount of misery, disease, poverty and death might, according to Reid, be prevented by the introduction of suitable sanitary regulations.

Such were some of the conditions prevailing in the first half of the nineteenth century. It will be useful now to sketch some of the conditions under which the working classes of the present day live, in this the first part of the twentieth century.

In London at the present day there is a rich field for the study of the social conditions of the working class. The industrial side of London differs very largely from that of the provinces. In London there is no staple industry, such as cotton in Manchester, wool in Yorkshire, or shipbuilding and engineering at Newcastle. Trades decline in London and shift their locality, but the body of trade shows no decrease, and the industrial position of London, both as regards variety and magnitude, remains unique. An interesting feature of industry in London is that there is still a large class of small workers who carry on trade at their own homes, either supplying the material, or having it supplied to them. This is a quaint relic of an older industrial system which still has a strong hold in London. In the provinces the trades are larger and more completely centralised. In London one half of the population lives, as it were, on the other half, and there is an advantage in having these small methods of business which allow of close touch with both customers and employees, and which, if they fail and are superseded, cause comparatively little economic disturbance. These smaller businesses come and go and alter in a way that larger undertakings could not do. The tendency to physical deterioration in London is being constantly stemmed by the influx of fresh blood from the provinces. If left to itself, the industrial force of London would rapidly decay, and as it is, the physical deterioration of its workers tends to produce a supply of workers who are inefficient, and therefore ill-paid, and who tend to keep down the wages of the more efficient.

The presence of the alien in such trades as jewellers, furriers and tailors, also tends to add to the stress on individual wage-earners, though, as Booth points out, this process is not necessarily inimical, for this influx may actually create new industries, or may attract trade to London from the efficiency of the labour in certain directions.

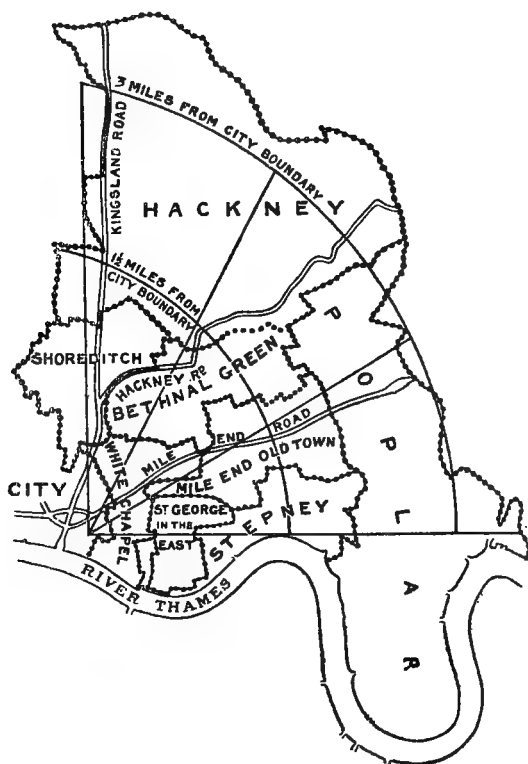


FIG. 9.

Charles Booth * has made a very valuable and extended study of the conditions of the labouring class in London, and has produced a work which will always be a valuable mine of information for the social worker. In the accompanying diagram a sector of London is taken lying between

* "Life and Labour of the People in London," by Charles Booth, Macmillan & Co., London, 1902.

Kingsland Road, running due north, and the River Thames, which may be roughly taken as lying at right angles. A circumference drawn three miles outside the city boundary encloses a quadrant which comprises within its boundaries a large, populous, industrial area of London (see Fig. 9). In the upper or northern half of Hackney the houses are large and commodious, and accommodate the richer class from the city who find it convenient to live near their work, such as those who work in the various city markets, stockbrokers, city clerks and so on. This portion of Hackney is healthily situated on the northern heights of London, and from the summit it slopes down northwards and eastwards to the wide marshes of the valley of the River Lea. The Hackney Marshes extend eastwards, and are still but little built upon.

But the remainder of Hackney, and from there south to the river, is densely packed with an industrial population of the poorer type, among whom lives a large Jewish alien population, which adds a touch of oriental colour to what is often a drab and dreary prospect.

Booth calculates that the population of this sector is 909,000, and he divides the community into eight divisions, which may be represented as follows :—

(A) lowest class of occasional labourers, loafers and semi-criminals ;	} = 314,000, or 35 per cent. classes in poverty ;
(B) class with casual earnings—very poor ;	
(C) class with intermittent earnings	
(D) class with small regular earnings } poor ;	
(E) class with regular standard earnings ;	} = 577,000, or 65 per cent. classes in comfort.
(F) higher class labour ;	
(G) lower middle class ;	
(H) upper middle class.	

Naturally, the proportion varies in different districts. Thus, St. George's in the East, which is the poorest district, has 23,000, or 49 per cent., of its population living in poverty, while only 24,000, or 51 per cent., live in comparative comfort. When two or more persons make their home in one room, or four or more in two rooms, or six or more in three rooms, overcrowding is considered to exist, and these persons are

considered poor. Speaking generally, the family consists of $4\frac{1}{2}$ to 5 members in the labouring classes, and of $3\frac{1}{2}$ to $4\frac{1}{2}$ in the professional classes. Taking the family as a unit consisting of 4.33 per cent., the term "poor" is held to apply to those where the wage of the head of the family does not exceed from 18s. to 21s. weekly. The "very poor" are those who live three or more in one room, and whose wages fall below this standard. In the poorer parts of London most of the houses have a frontage of from twelve to fifteen feet only, and of this about three feet is devoted to entrance passage and stairs. The front room on the first floor has usually two windows, and occupies the whole breadth of the house. This may be repeated on the floor above. The other rooms are all somewhat smaller. The largest size commonly found is about twelve feet by fourteen feet, and the smallest about eight feet by eight feet. The height from floor to ceiling varies from eight feet to ten feet. It is in rooms of this character that 314,000 persons in this one sector of London are living two or more in one room. The majority of these persons are not in actual want. As Booth states, though they are neither ill-nourished nor ill-clad, according to any standard which can reasonably be used, their means are barely sufficient for decent independent life, and their lives are an unending struggle and lack comfort.

Tested by the conditions of overcrowding in which they live, street-sellers, coal porters and dock labourers are the poorest section of the population. The following classes are taken from all over London, and not only from the north-eastern sector, and the tables show the degree of overcrowding present in the various classes :—

	Families living two or more in one room.	Families living three or more in one room.
(1) Street-sellers	... 69 per cent.	36 per cent.
(2) Coal porters	... 65 "	30 "
(3) Dock labourers	... 63 "	28 $\frac{1}{2}$ "
(4) General labourers	... 58 $\frac{1}{2}$ "	26 "
(5) Carmen	... 56 "	27 "

In this scheme the figures in the first column naturally include those in the second column. These five sections of

the labouring community include in all 88,469 heads of families, or a total of 399,690 persons, of whom no fewer than 235,281 exist under crowded conditions, that is two or more in one room, and of these 109,390 are so crowded as to be living three or more persons in one room. These figures indicate an appalling amount of poverty and discomfort among those engaged in these occupations. Not only is there poverty and discomfort, but ill health and increased mortality are the necessary accompaniments. Nowhere do these conditions tell more directly than on the young infant. In these houses when the family lives in two or three rooms there is no proper kitchen, and the cooking and washing have to be done in the living rooms. Such a thing as a bath is unknown. For long periods during the winter months the child is kept continuously indoors in a close and confined and vitiated atmosphere. Sunshine, fresh air, and exercise are all lacking at this, the most critical period of its growth. The child lives in a close and foul atmosphere, in which one would not dream of attempting to grow the humblest form of plant life. As regards food, the baby may not fare so badly. Whoever goes short, care as a rule is taken that the infant receives its due share of nourishment. Whatever milk is obtained is reserved for the infant.

To revert to the north-east quadrant of London already marked out, the following statistics are the result of an enquiry to ascertain the rate of incidence of the disease, among some fifteen hundred of the London County Council school children living in this area. It was found that rickets was exceedingly common. It is not an easy matter to get uniform statistics as to the degree of prevalence of rickets throughout the country. Rickets is eminently a curable disease and tends to end in recovery. If in school statistics only children actually suffering from rickets at the time of examination are shown, the figures will be very misleading, for by the time the children reach school age, from three to five, they are making their way towards partial recovery. In the East End of London, by taking into consideration the stigmata of rickets left in the skeleton, teeth and elsewhere, it was

found that 80 per cent. of the children examined were suffering or had suffered from rickets in the first two or three years of their lives.* So commonly is this disease found that it may be stated that practically all children living under the slum conditions which prevail in the East End of London have to struggle through a rickety phase of their existence, during which the whole tide of growth is profoundly disturbed, and permanent damage is done to the body tissues and skeleton, and even to the sensitive tissues of the central nervous system. The only means by which rickets can be diagnosed with certainty is by making a histological examination of the bones themselves. Schmorl found in the post-mortem examination of 386 children dying under the age of four years that 345, or 89·4 per cent., presented histological evidence of rickets. These figures agree with the rate of incidence of the disease found clinically in the East End of London. Before statistics can be relied upon there must be a uniform standard for observers, and it is essential in examining children after the age of three or four that consideration should be given to the signs of past rickets, for many children who have had the disease are by that time making rapid strides towards recovery. In making the above-mentioned examination the card given on page 364 was used for record purposes.

For the first enquiry, one thousand children were taken from schools in the districts of Whitechapel and Stepney. These schools were largely filled by the alien population resident in these parts, and about 80 per cent. of the children were Jewish. But it must not be supposed that the disease is more common among the Jewish children than among the non-Jewish. Rickets was found to be equally common among the non-Jewish children, and was of a notably severer type than among the better-fed Jewish section. Indeed, race and feeding seemed to have no effect on the incidence of rickets, but, as might be expected in a nutritional disease, feeding had a marked effect on the severity

* "Defective Housing and the Growth of Children," by J. Lawson Dick, London, 1919, Chapter II., p. 22.

RICKETS.

Name

Date of birth

Address

School

Standard

Age	Height		Weight		
Mental capacity	...	...	Bright	Average	Backward
Breast fed	...	...			
Delayed development	Walking				
	Speech				
Beaded ribs	...	...			
Cranial signs	...	...			
Catarrhal signs	...	...			
Hypoplasia	Deciduous				
	Permanent				
Other defects	...	...			
Nutrition	...	...			
Remarks	...	...			

with which the individual child was affected. The excellent state of nutrition of the Jewish child is a factor of much importance in considering the part played by the nutrition of the child on the severity of rickets. Jewish women make excellent mothers, in so far as their children are well fed and clothed. Indeed, the tendency is to overclothe the child, and it is often difficult to persuade the mother to discard the extra waistcoats and jerseys with which the child is hampered. But the essential point is that these children do not suffer from cold, bleak winters to the same extent as poorly-clad non-Jewish children. The fat nutrition of these children is usually very good, and yet, in spite of excellent nutrition, rickets is exceedingly common.

Early Feeding during Infancy.—Of these one thousand children :—

81.4	per cent.	were breast fed,
18.6	„ „	artificially fed.

Almost all bottle-fed children were brought up on cow's milk ; comparatively few Jewish mothers use patent foods or condensed milk. Breast-fed children are children who were suckled on the breast for a period of six months or more ; if they were not suckled for six months, they are included among the children who were not breast-fed. Of children nursed on the breast the following is the duration given in percentage results :—

2	per cent.	suckled from	6 to	9 months.
17	„	„	9 to 12	„
61	„	„	12 to 18	„
20	„	„	18 to 24	„

That is, 81 per cent. of these mothers gave their children the breast for periods varying from twelve months to two years. This prolonged lactation is important, but care must be taken not to exaggerate its influence, as from eight to nine months onwards the mother gives additional food from the general table besides the breast milk. But breast milk is the main support of the child for the first eighteen months or two years. On the other hand, at the Hackney Centre

for mothers, where the mothers are almost entirely Christian, out of three hundred attending during the year :—

57·5 per cent. nursed their babies entirely on the breast,
 20·5 per cent. nursed their babies partly on the breast and
 partly on the bottle,
 22 per cent. were bottle fed.

Unfortunately many of these mothers were out working during the day, and so had to give the baby the bottle during the day, reserving the breast feeding for the night. The Jewish mother seldom goes out to work in this way. Among the non-Jewish mothers the use of patent foods, especially condensed milk, is common. Yet even in the case of the Christian mothers the figures show that 78 per cent. nurse their children either wholly or partially on the breast. The poorer classes of mothers, Jewish or Christian, do their duty to their babies in the matter of breast feeding. The fault so far does not lie with the mother.

Of the one thousand children examined :—

798 were rickety = 80 per cent.
 202 were not rickety = 20 ,,

It must be understood that these 798 children were not necessarily suffering from rickets at the time of the examination ; indeed, the majority had recovered, but showed signs of having suffered at one time from rickets, and these rickety stigmata persisted through the child's school life. Rickets is essentially a disease of the first two years of life ; but its consequences are far-reaching, and the persistence of the recognisable physical signs affords an index to the lasting damage done to delicate tissues, especially those of the nervous system.

It is still taught that, for all practical purposes, breast feeding excludes rickets. This is a grave error. Of breast-fed children 72·5 per cent. were rickety ; while of bottle-fed babies 87 per cent. were rickety. A percentage of 14·5 fewer children showed signs of rickets amongst those who were breast fed ; but this still left 72·5 per cent. breast fed who showed evident signs.

Nutrition of the Rickety Children.—The state of nutrition of those eight hundred children who showed evident signs of rickets may be assessed in three groups :—

- (1) of *very good* nutrition, of which there were 23 per cent. ;
- (2) of *good* nutrition, of which there were 57 per cent. ;
- (3) of *bad* nutrition, of which there were 20 per cent.

In only one-fifth of these children was the nutrition decidedly poor. This result is very good, and would, in the East End of London, be obtained only in a Jewish school. For this reason Jewish children were purposely selected, for here we have a natural experiment at hand, where good nutrition, notably good fat nutrition, is associated with extremely defective housing conditions as regards want of ventilation, overcrowding, and disregard for general cleanliness.

Beaded Ribs and Chest Deformities.—The chest signs of rickets are the most common and most constant. Beading of the ribs, if slight and if present alone, was not taken as a sign of rickets, unless there were chest deformities or cranial signs to confirm the diagnosis. In the ordinary inspection of school children beading of the ribs will be found in over 80 per cent. if carefully sought. With this beading of the ribs certain chest deformities are frequently associated. Asymmetry of the chest is common, such as a tendency to flattening at the left apex, with a compensatory projection to the right side of the lower part of the sternum, where it meets with the lower true ribs. This is usually the result of a slight lateral curvature, which, in the milder cases, can often be diagnosed more easily from the front than by examination of the spine itself. Which apex is flattened and which shoulder is elevated will vary with the form of lateral curvature present. It is noteworthy that impairment of the resonance at one or other apex, with flattening, is frequently due in school children to distortion of the chest and not to tubercle. Another of the slighter deformities of the chest is an elevation of the manubrium sterni at the sternoclavicular joints, so that the whole chest seems as if it were tilted forwards and raised. The everted edge of the margin

of the ribs where it has been pushed outwards by the enlarged abdominal organs, and the associated transverse Harrison's sulcus associated with falling in of the ribs above this margin are well known. Not infrequently the whole sternum is pushed forwards, and the ribs tend to sink in at the sides, to produce the various forms of pigeon breast so characteristic of rickets. When all the ribs are soft the whole sternum projects, and the chest is furrowed laterally as high as the second rib. Not infrequently, however, the upper part of the chest is moderately well expanded, and the somewhat keel-shaped protrusion of the sternum is confined to the lower end, and the retraction of the ribs to the infra-mammary region. The beading of the ribs is probably Nature's attempt to buttress up the weak point at the junction of the ribs with the costal cartilages. The constantly varying strains on this part tend to produce an irritative overgrowth, the result of which becomes palpable very early in the child's life, and which is greater on the inner side of the ribs than it is on the outer.

These defects are common in children not at first suspected of rickets.

Antero-posterior flattening of the chest is very common, and is often associated with the stooping shoulders and arched back so commonly seen in rickety subjects.

Cranial Signs.—These are only second to the chest signs in frequency and importance. Of the eight hundred rickety children *both cranial and beaded ribs* were present in 70 per cent. ; *beaded ribs alone* were present in 24 per cent. ; *cranial signs alone* were present in 6 per cent.

In the early months of infancy, when rickets is in active progress, the cranium typically has a somewhat expanded appearance as if the bones were thinned out. The widely open fontanelle and the thin skin with the blue veins showing through over the prominent forehead form a characteristic picture. When we have to deal with children of school age, the expanded appearance is lost, and the head is now massive-looking, and gives an impression as if the bones were greatly thickened, as is usually the case, especially along the lines of the sutures. There is a characteristic heaping-up

of bone in the region of the anterior fontanelle, and from that in a somewhat broad band along the line of the coronal suture. Often the whole frontal bone appears thickened and the forehead prominent and projecting, but there is not the same tendency to bossing on the frontal region as in congenital syphilis. Very common and striking is the bossing over the parietal regions behind, which forms one of the most characteristic and persistent signs of rickets in the child's skull. (See Fig. 3, p. 119.)

Tonsils and Adenoids.—Tonsils and adenoids are commonly associated with rickets. Thus, of eight hundred rickety cases, 21 per cent. suffered from either enlarged tonsils or adenoids.

Of these children suffering from either tonsils or adenoids:—

14 per cent. had enlarged tonsils,
20 per cent. had adenoids,
66 per cent. had both conditions.

Anæmia was found to be marked in 20 per cent. of the rickety children.

Catarrh.—Associated with the conditions of tonsils and adenoids, and anæmia, is that of catarrh, which was carefully enquired into, to ascertain what influence rickets might have in producing catarrhal conditions likely to predispose to tubercle. Catarrh was present in 18 per cent. of the rickety children, mostly cases of persistent bronchial catarrh and nasal catarrh, the bronchial condition being much the more common. Cases of acute coryza and ordinary coughs and colds which might be accidental were not included. These catarrhal defects were common among Jewish children, but still more so among the poorer non-Jewish children. This difference in favour of the Jewish children is possibly due to their good fat nutrition, which tends to prevent their developing catarrhal conditions.

Other Defects associated with Rickets.—Of other defects, several were characteristic, but were not present in sufficient numbers to be set down in percentage results. Stooping

shoulders and lateral curvature are common, though, as already stated, the slighter forms of lateral curvature are more often suggested by flattening at one apex and prominence of the opposite side of the chest, with raising of one shoulder, than by an actual examination of the spine itself. Syphilis and rheumatism were exceptionally found in a few cases.

While pulmonary tubercle was not often found, enlargement of the submaxillary and cervical glands was common. This enlargement of the glands was usually of a discrete or shotty nature, and glandular abscesses of the neck were quite infrequent. This enlargement, indeed, is a part of the general hypertrophy which in rickets takes place in the whole of the lymphoid tissue, lymphatic system, and spleen.

A very characteristic defect, present fairly frequently, was a harsh, dry condition of the skin, especially over the back of the upper arm and the back of the shoulders, but not infrequently extending over the whole body and face. As a rule this condition was associated with coarse, dry, lustreless hair, which was often scanty. All these conditions have already been dealt with in detail in discussing the changes found in the various systems in rickets. This has already been fully dealt with in speaking of skin affections in rickets.

CHAPTER XXV

The Relationship of Rickets to the National Health as Revealed in the Army Recruiting Records

ON November 1st, 1917, the Ministry of National Service began its organised work, under the Military Service Acts, of surveying the whole of the nation of military age and classifying individuals according to their physical fitness. Four grades were constituted, and as a guide to the Medical Boards examining recruits, these were defined as follows :—

Grade I.—men who attain the full normal standard of health and strength, capable of enduring physical exertion suitable to their age :

Grade II.—those who from various partial disabilities do not reach the standard of Grade I., but who do not suffer from progressive organic disease. They must have fair hearing and vision, and be of moderate muscular development, and capable of standing a considerable degree of physical exertion not involving severe strain :

Grade III.—those who present marked physical disabilities or such evidence of past disease that they are not considered fit to undergo the degree of physical exertion required for the higher grades :

Grade IV.—all those who are totally and permanently unfit for any form of military service.*

The result of grading for the year from November 1st, 1917, to November 1st, 1918, gives food for serious reflection. During the year 2,425,184 examinations were made of men of military age. They were classified as follows :—

Grade	I.	...	871,769	36	per cent.
„	II.	...	546,276	22·5	„
„	III.	...	756,859	31·5	„
„	IV.	...	250,280	10	„
			2,425,184	100	

* Ministry of National Service, 1917-1919, Report (Vol. I.) upon the Physical Examination of Men of Military Age by National Service Medical Boards from November 1st, 1917, to October 31st, 1918.

That is to say that of every nine men of military age in Great Britain, on the average three were perfectly fit and healthy ; two were upon a definitely infirm plane of health and strength whether from some disability or some failure in development ; three were incapable of undergoing more than a very moderate degree of physical exertion and could almost, in view of their age, be described with justice as physical wrecks ; and the remaining man was a chronic invalid with a precarious hold upon life. Full consideration, it is stated in the report, was given to the fact that this was the fourth year of the war, and that already many calls had been made on the manhood of the nation, and also to the fact that the figures represent examinations of men who were examined twice, and who appear as two individuals. But in spite of these facts the investigating committee considered that the above figures fairly represented the health and physique of the general community at this time.

Such a statement requires the most careful examination. Unfortunately the report does not state on what grounds it was held that these important facts did not affect the results obtained. Of the great value of the figures and the charts obtained as the result of the examination by the National Service boards there can be no question, but the inference drawn from these figures that they form a true estimate of the state of the national health will not bear critical examination.

Much harm has been done in past years by the publication of alarmist reports as to the health of the nation. These reports have mostly been intended to awaken the country, but have signally failed to carry conviction because it is apparent to the common sense of the people that these statements are exaggerated. In school reports high percentages of the children are marked as defective. It is self-evident to the community that if these defective children were taken to their own medical man the parents would be informed that no fear as to the child's health need be entertained, but that some minor defect, such as one or two carious teeth, or some impairment in the vision, or possibly otorrhœa, required attention.

The dangers of such conditions, if neglected, might with advantage be pointed out, and ought to be pointed out, but to mark such children as defective and to draw conclusions by massing such defects together and representing them in percentage results is not only misleading, but has a tendency to defeat its own object.

The National Service Report makes statements of such a serious nature as to the health of the nation that it is very necessary to enquire into the grounds on which these conclusions have been come to. It is difficult to believe that the fact that the Ministry only took up its work in the fourth year of the war did not affect the results obtained. And yet it is stated that while full consideration was given to this fact, the conclusion was come to that it did not materially affect the result. Certainly in the treatment of the sick and wounded from the various battle fronts the general experience was that it made a very material difference whether the patient belonged to the original army or to the voluntary recruits on the one hand, or to the defective class who were recruited late in the war, on the other. The men of the old army and the volunteers of the first two years of the war were a class by themselves and had a stamina and a power of resistance to wounds and disease which were of the greatest value in their treatment, factors which were notably absent in the recruit who was accepted late in the war. Again, the fact that a man examined twice or three times was counted as a fresh individual each time is a matter of importance. Many were examined two or more times, and in the majority of cases these were defective men whose enlistment into the service was postponed on that account. Obviously it is of great importance to know the number of men who were so re-examined.

The fact that in less than 4 per cent. only the decision of the Board was not upheld on appeal, the category being lowered, is thought to be evidence of the accuracy of the Board's work. This is open to the obvious objection that an examination which only classes one man in three as Grade I. does not leave much ground for appeal. The

leniency of the examination is also borne out by the fact that in many cases men of low category arriving in Egypt, for instance, were immediately reclassified and placed in Grade I.

The following are the figures of the full strength in the army and navy as supplied to me by the War Office and the Admiralty up to November 1st, 1917, the date on which the Ministry of National Service took over the recruiting administration. The total number recruited by the War Office from England, Wales, Scotland and Ireland, between the dates August 4th, 1914, and October 31st, 1917, inclusive, was 4,421,694. The approximate strength of the *personnel* of the navy on November 1st, 1917, was as follows :—

1. Serving afloat and in naval establishments	327,635
2. Serving in the Royal Naval Air Service ...	45,133
3. Serving ashore	41,345
Total naval <i>personnel</i>	414,113

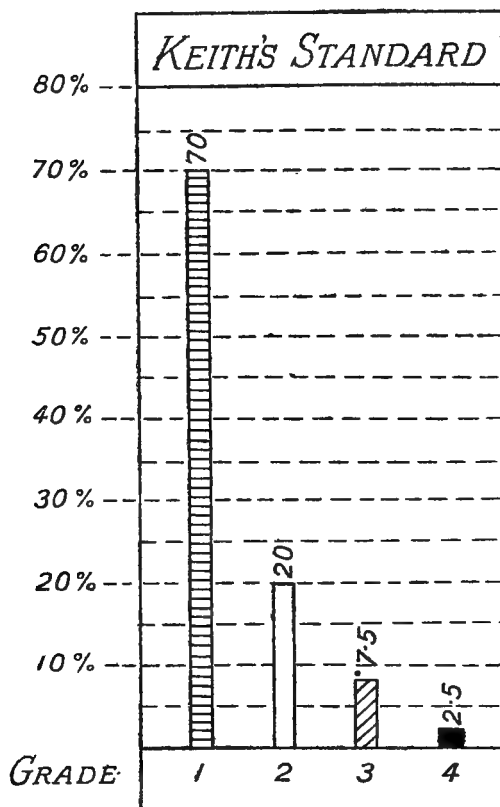
This gives a total of 4,835,807 recruited at home who were already serving on the *personnel* of the army and navy on November 1st, 1917. These were not all fit men, but the fit men of the nation of military age were certainly included in this number.

In England and Scotland on this date 11·5 per cent. of the total population was represented by enlistments, and practically one-quarter of the estimated male population was already serving with the army and the navy. It must be remembered that these represented the best element of the nation. Large as the numbers were with which the Ministry of National Service dealt, it is reasonable to suppose that the abstraction of such large numbers of fit men from the male population must have materially affected the results of the examination.

For these and other reasons, the figures given by the report cannot be accepted as a true estimate of the health of the nation. With this proviso, however, the study of the report is of the greatest value as giving a rough estimate of

the existence of an enormous number of disabilities, and a degree of impairment in the national standard of health which had never before been realised.

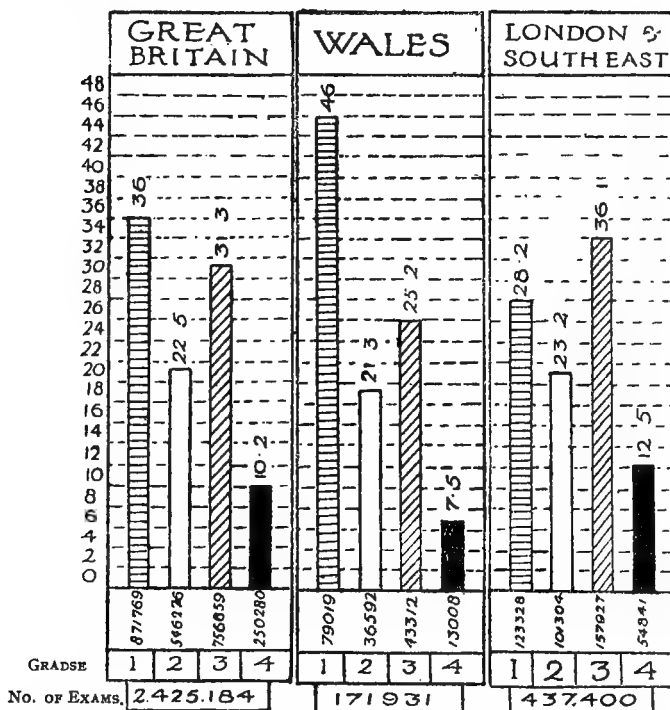
Sir Arthur Keith suggested the following standard as one which a fit population might reasonably be expected to



attain. A standard which expects to find seventy men who have attained the full normal development of health and strength, and are capable of enduring physical exertion suitable to their age, among every hundred men of military age can hardly be regarded as unduly exacting.

Below are three graphs taken from the Ministry of National

Service Report which may be usefully contrasted with Keith's standard. These show the actual results obtained by the National Service boards as the result of their examinations. The graph for Great Britain shows the average for the whole country while that for the London and south-eastern region is the lowest result obtained, and that for Wales the highest.



It will be seen that all these graphs fall lamentably below the very modest standard suggested.

Comparing the graphs of the general average for Great Britain with Keith's standard, the results may be summarised by saying that in round numbers the physical census showed a shortage of 825,000 Grade I. men, an excess of 61,000 Grade II. men, and the alarming excess of no less than 575,000 Grade III. men, and 190,000 Grade IV. men.

In the following tables the results may be put into figures as follows : Normally any 1,000 young men collected from a population of good health and physique should approximately be divided as follows :—

Grade	I.	...	...	...	700
„	II.	...	...	...	200
„	III.	...	...	...	75
„	IV.	...	...	...	25

that is 10 per cent. of unfit men should be expected. A typical recruiting survey from an industrial town yields the following disastrous results :—

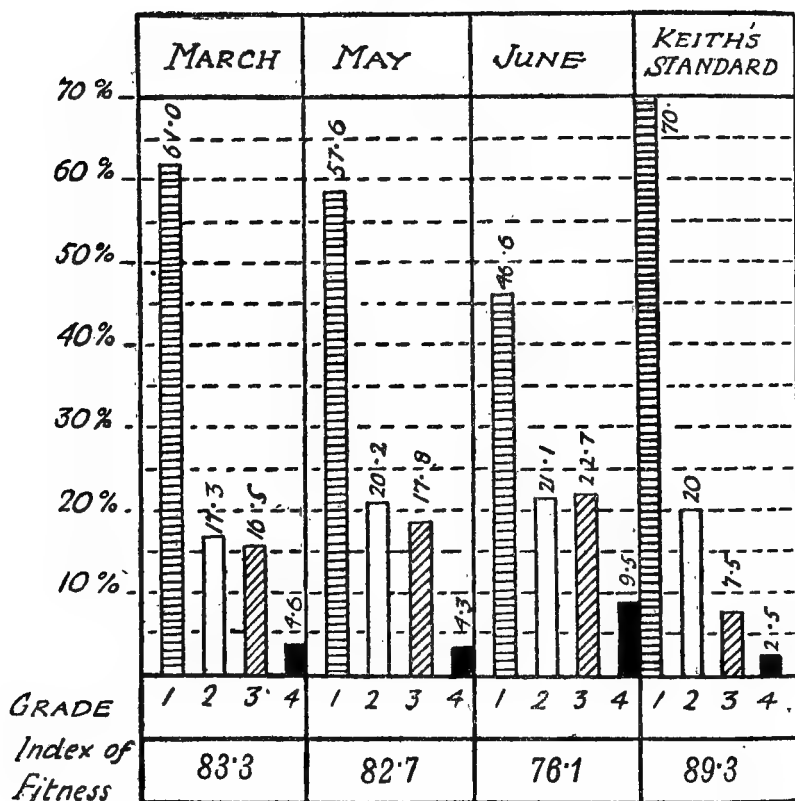
Grade	I.	...	...	...	190
„	II.	...	...	...	270
„	III.	...	...	...	410
„	IV.	...	...	...	130

As the committee remarks, this is a serious conclusion which calls for the closest scrutiny.* In considering the healthiness or unhealthiness of certain occupations it must be remembered that there is a constant tendency for the population to grade itself. Attention has already been drawn, in speaking of the industrial population of London, to the steady flux which is constantly going on in the labour market. The environment is such that a steady deterioration occurs in the value of industrial labour which is constantly being made good by the introduction of fresh blood from the country and the provinces. But the position remains serious, for the tendency is to the formation of a large class of inferior labour, notably in the East End of London, which is unable to find a proper wage for its support and readily lends itself to casual and sweated labour. Miners and workers in metals can hardly be said to follow occupations the environment of which is conducive to the preservation of good health, but they are occupations which demand a large output of energy and can only be followed by the healthiest and most muscular section of the community. The labour in these occupations is well paid and attracts the virile portion of the population. Thus

* *Loc. cit.*, p. 12.

in the western valleys and the eastern portion of Carmarthen the percentage of Grade I. miners reaches a higher point than in any part of Wales ; these miners are usually the sons of farmers who remain on the land and send their sons to the

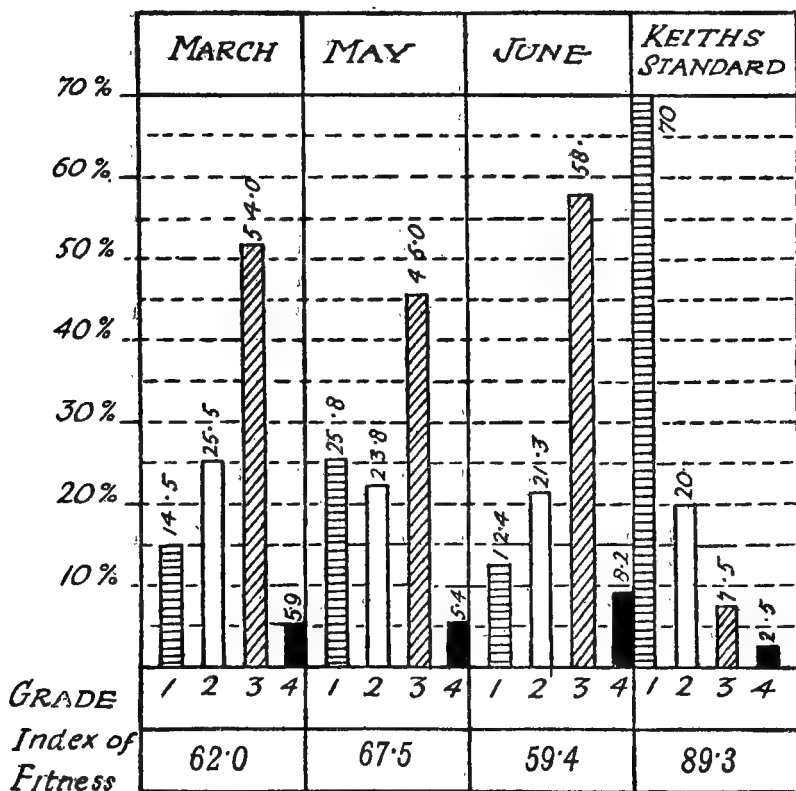
SHEFFIELD.



collieries. Therefore the type of man who becomes a miner is good ; he is born and bred on the land in healthy surroundings, totally different from those obtaining during the childhood of most of our industrial population. This tendency of the population to grade itself is strikingly exemplified in the case of Leeds and Sheffield, two great

industrial centres lying within thirty miles of each other, and both drawing their labour from a common source. The superiority of physique of the Sheffield worker is well brought out in the accompanying graphs, the result of grading for army purposes during the months of March, May and June, 1918.

LEEDS.



In Sheffield the industrial population is almost entirely employed in the iron and steel industries—a class of labour which requires men of good physique and wherein there is but little opening for the female worker. In Leeds the chief industry is woollen and cloth manufacture. Artificial silk is also extensively made, and the leather trade is the largest

in England. Women are employed in large numbers in the factories.

Following the law of supply and demand, there is a natural tendency for the available labour to separate itself and to take up the occupation for which it is best fitted physically and temperamentally. The result of this natural cleavage is, that while both towns fall markedly below Keith's standard, Sheffield in the above tables was able to supply 55 per cent. Grade I. men to the army, while Leeds could only yield 17.5 per cent. Great caution must be observed in estimating the effect of industrial conditions on adult labour. Thus it might easily be argued that there must be something in the industry of Leeds inimical to the welfare of the worker as compared with the iron and steel industries of Sheffield. If the health of the two towns is viewed from another standpoint a different result is obtained. An excellent criterion of the health conditions of a community is to be found in the incidence of child mortality. The infant in Sheffield would seem to have many advantages as compared with the child in Leeds. Two important factors are in its favour, namely, the better physique and the greater virility of the father and the fact that the employment of female labour is not common, whereas in Leeds the physique of the parents is poor and female labour is very commonly employed. The result is quite different from what might be expected, for taking the total death-rate from all causes at ages 0-5 years per 1,000 births the figures are :—

Sheffield	..	..	..	209
Leeds	..	..	..	202*

The death-rate for both towns is very excessive and is somewhat greater in Sheffield than in Leeds. Differences in feeding will not account for this for the advantages are still with the Sheffield infant. The explanation lies in the fact that in both towns the children are reared under home conditions entirely inimical to their proper growth and develop-

* " Report on Child Mortality at Ages 0-5 in England and Wales," Forty-Fifth Annual Report, Local Government Board, 1916.

ment. These deaths take place before pulmonary tuberculosis plays any large part in increasing the mortality. It is significant that in both towns rickets is very prevalent.* The evil environment tells in two ways—by keeping up a high mortality among the children in the poor neighbourhoods and, what is more important, by producing a greater degree of ill-health amongst those who survive, so that the whole development of the child is backward and defective, resulting in weakly adults who formed Grades III. and IV. of the population during the late war.

Much has been done to improve the conditions under which the industrial labourer works. The building of hygienic factories, the better ventilation of mines, the regulation of the hours of labour, and the control of child and of female labour, are all matters of importance and are capable of control by legislation. The grosser evils inimical to the health of the labourer in the factory and workshop have now been largely done away with.

But the depreciation of the health of the nation with which we are now dealing is not the result of the environmental conditions of the industry affecting either the child or the adult worker. It is the environment of the young infant during its first years of life which is the important factor, and in rickets this is the all-important factor which is at fault, and which leads to the wide diffusion of the disease through a large section of the community. The ever-increasing tendency of the population to centralise into large industrial areas, and the evils associated with crowded communities living under slum conditions, strike at the very foundations of the health of the nation, for they produce their maximum effect on the young infant inducing not only a high mortality but leading to ill-health and perverted and stunted growth in the survivors.

Summarising the results of recruiting in Sheffield and Leeds in particular, and speaking generally of the Yorkshire

* "Geographical Distribution of Rickets, etc.," Reports of the Collective Investigation Committee of the British Medical Association, January, 1889.

and East Midland region, the Commissioner of Medical Services gives six causes for the variation in the results of grading in the various areas.* The sixth and most important cause of variation he believes is due to the conditions under which the people live either at their work or at their homes. "This last cause has in my opinion," he states, "most far-reaching effects on the standard of health of the nation; for it is in their homes that the young (up to fourteen years) spend their lives when environment has the most marked effect on the physical and mental development of the individual, and my contention is that if an analysis were made of the children born in the slum districts and who eventually grow up Grade I., the result would be so appalling that no Government would have the slightest difficulty in passing any measure which would remedy this evil. Until we tackle this problem thoroughly and are prepared to spend a large sum of money in improving the surroundings of the young, no other remedies will raise the index of fitness to anything like what should be a normal level, and in fact would be almost useless."

The Commissioner of Medical Services for the eastern region is in the happy position of being able to state, referring to recruiting in Northampton, that there are no slums in Northampton and that the houses are mostly modern and are built of brick.† It is interesting to note that these improved conditions are immediately reflected in the infant death-rate, which the Local Government Board's report on child mortality for 1916 shows is 146 per 1,000 for children of ages from 0-5 years, contrasted with 209 in Sheffield, and 202 in Leeds.

During the active recruiting in the spring of 1918 the returns in grading from certain of the medical boards in the north-western region showed such wide variations that an enquiry was made as to the cause of these differences. It was found that the explanation of the apparently anomalous results lay in the fact that some boards were dealing wholly

* *Loc. cit.*, p. 108.

† *Loc. cit.*, p. 117.

with miners, while others dealt with cotton operatives or, as the report phrases it, that the boards were dealing with different human material. The conclusion is come to that the differences in physique between the two classes represent the effects of their respective occupations and conditions of life, and that in the case of the cotton operatives, work in the moist and over-heated atmosphere of the mills, when extended over a long period, has a profound effect upon their health. This is only part of the truth. There is probably in all occupations a natural tendency for the worker to follow the employment for which he is most fitted, and while to say that a man is a worker in steel because he is healthy, and a tailor is a tailor because he is unhealthy, is a crude statement of the case, it is undoubtedly true that in such an instance as that of Sheffield and Leeds, where the labour is drawn largely from a common source, the fit men tend to follow the heavier and better-paid trades, while the weaker portion of the population tends to follow the occupations connected with soft goods in Leeds.

Some trades seem to have more continuity than others. In the case of the coal miner the occupation is hereditary, more perhaps than in other trades. To-day the mortality from phthisis is actually less among coal miners than it is among the general population, but when the heavy mortality from this disease among miners which existed some forty or fifty years ago is considered, it raises the question how far this improved result has been obtained by the elimination of the weaker section of the mining community in the past. In any case this improved condition in the health of the individual miner is not reflected in the health of the progeny, for, as has been shown, the areas of the greatest prevalence of rickets practically coincide with the distribution of coal mining and industrial regions.

Unlike the coal miner, the occupation of the industrial labourer in London tends to be a very fleeting one, which is reflected in the rapid flow and exchange which takes place in its population. Not only is there but little continuity of labour from father to son but the same individual frequently

changes his occupation according to the exigencies of trade. Many factors control the choice of a trade. Racial characteristics have an important influence. In the East End of London the foreign population, which is largely Jewish, follows such trades as tailoring and the fur trades, while dress-making and work in cigarette factories give employment to large numbers of the female portion of the community. Even as a school child the Jewish boy is not expert at hand-work such as carpentry, and in later life it is seldom that he takes up one of the heavier trades. The female portion of the population is domesticated in a high degree, but it is nevertheless exceedingly rare for the Jewish girl to enter domestic service.

But the important point is that no matter what occupation is followed, immediately an area becomes an important industrial centre, the population tends to herd together in slums, living under housing conditions which depreciate the health of the adult, and which seriously interfere with the growth of the young infant and with the standard of fitness of the nation.

Efficient drainage of streets and houses has banished many of the filth diseases, such as typhoid and typhus fever, and has greatly improved the general health conditions. But the great problems of overcrowding and defective housing, instead of being solved have grown more troublesome and more complex with the great growth in population. In nearly every large town there is a considerable area where the streets are narrow and squalid and devoid of sunlight, where the houses are badly built, still frequently standing back to back and incapable of being properly ventilated. In the squalid and overcrowded rooms of these houses it is impossible for the adult to retain his health and vigour, and yet it is in these surroundings that the growing infant is expected to lay the foundation of a healthy and vigorous manhood or womanhood.

The north-eastern district of London, which has already been dealt with in some detail as regards environment (Fig. 9) and conditions of feeding, was specially marked

out in the recruiting campaign, with certain slight modifications, as a *black list area* by the Ministry of National Service, with a view to finding out what effect overcrowding and bad hygienic conditions had on the community. From a study of one thousand children taken at random from this area some little time before the war it was found, as already pointed out, that 80 per cent. showed definite signs of having suffered more or less severely from rickets, and the conclusion was come to that practically the whole of the infant population living in the slums of this area had to fight their way through a rickety phase during the first two years of life.* The examination of the recruits by the National Service Medical Boards gives the results of the examination of the adult of the same area at a time when an attempt was being made to call up every individual who was fit for any form of military service. The two following graphs are compiled from the examination of recruits during the period January to October, 1918. They are of interest as forming a comparison in relation to the health of a purely city population as distinct from a population largely rural and country town. The south-eastern region comprised Surrey, Sussex, Kent and Hampshire.

It will be noted that both charts are far below Keith's standard, but that the south-eastern region shows a very distinctly higher percentage of Grades I. and II. men, while the percentage of Grades III. and IV. is distinctly lower. The figures for the London region include the *black list area*. During the period under consideration, January to October, 1918, 8,244 examinations were made in this area. If the ineffectives as comprised in Grades III. and IV. in this area alone be compared with the figures for the whole of London, including this area, the following result is obtained :—

	Grade III. Per cent.	Grade IV. Per cent.	Per cent.
Black List area	... 42.4	20.85	= 63.25
London region	... 36.5	12	= 48.5

* "On the Incidence of Rickets in School Children," by J. Lawson Dick, *School Hygiene*, May, 1916.

That is 63·25 per cent. of men examined in the black list area were placed in Grades III. and IV., as compared with 48·5 per cent. for all London. Naturally, if the figures from this very defective area were taken out of the consolidated

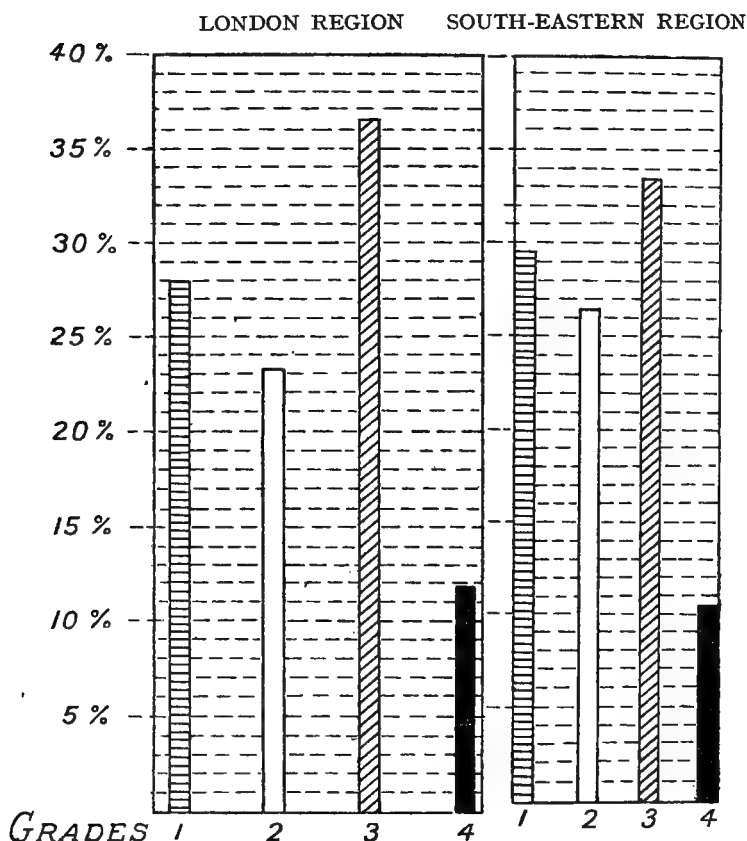


chart for the London region the contrast would be still more marked. In other words, the appalling result is obtained that well over five thousand men out of 8,244 examined in the black list area were suffering from disabilities which only allowed them to be placed in Grades III. and IV. when their fitness for military service was considered.

Three series of observations, then, have been made in this north-eastern sector of London, viz.: (1) a systematic examination of the children immediately prior to the war, which showed that 80 per cent. suffered from rickets or had passed through a rachitic phase; (2) a special examination of recruits during the late war, 1918, which showed that 63·25 per cent. of the male adult population of military age were practically useless from a military point of view, even when a very low standard of fitness was required; (3) a special study of the environment surrounding the population, in which the chief factors were defective housing with lack of sunlight and fresh air, associated with the breathing of vitiated air, and the want of exercise, all conditions which bear especially on the infant and young child during the first two years of life. It is not held that every failure in adult life is due to rickets, but it is maintained that these later disabilities in the adult have their origin in the first and second years of life, and that the most common and the most far-reaching factor affecting the health of the infant at this early period is rickets.

The following figures are of interest as showing the cause of rejection of recruits in London in the early days of the war from August to December, 1914. Of the primary causes of rejection it was found that there were:—

under height standard ...	...	...	3·28	per cent.
under chest measurement ...	...	...	34·98	„
congenital and acquired deformities ...	...	...	1·72	„
disease of ear and deafness ...	...	...	1·77	„
defective teeth ...	...	...	6·35	„
				48·10
				„

These disabilities, totalling 48·10 per cent. of the primary causes of rejection of recruits, are nearly all due to faulty growth and development, and are most frequently associated with rickets, and are indeed usually its direct result.

In Liverpool, during the period November 1st, 1917, to May 31st, 1918, an analysis of the grading of 12,699 recruits

of all ages, from under eighteen years and eight months to forty years and over, gives the following results :—

Grade	I.	...	...	...	3,335
	„	II.	...	...	2,381
	„	III.	...	...	4,116
	„	IV.	...	...	1,392
Examinations deferred					1,475
					12,699

That is, taking Grades I. and II. as efficient and Grades III. and IV. as inefficient, it is found there is only a difference of 208 in favour of the first group :—

total number of Grades	I. and II. recruits	= 5,716
total number of Grades	III. and IV. recruits	= 5,508
		Difference = 208

In an analysis of the cause of rejection of 2,894 Liverpool men from November 1st, 1917, to July 31st, 1918, it was found the following disabilities occurred in these proportions :—

physical defects	...	...	20.6 per cent.
poor physique and debility	...	8.5	„
deafness and otitis media	...	4	„
			33.1 „

In grading large numbers of men, several methods might be employed for finding out their index of fitness, each of which would give equally useful results when taken over large numbers. Thus, men might be graded :—

- (1) by height and weight alone :
- (2) by estimating the exercise tolerance or the reaction of the body to exercise and noting whether the symptoms of fatigue or distress were in excess of what would be produced in a normal person of the same age. This is the test the application of which revealed the existence of a large class of men who, without any actual organic disease, were suffering from constitutional weakness, and who broke down at an early date in the war, frequently being classified and sent home as cases of

disordered action of the heart. To this class belonged many undersized men, often with flat or elongated chests, with a history of debility in early childhood, who had suffered from the evil effects of faulty environment from their earliest infancy. In the main these are the representatives in the adult, of the class who in early childhood had suffered from rickets, and who had made an incomplete recovery. In civil life they formed the least effective portion of the population although they were, as a rule, able to earn a living. When, however, the unaccustomed strain of army training was applied to them they speedily broke down :

- (3) the third method of examination, and the one which was actually employed, was a careful medical examination of the various systems of the body and a study of the history and the personal statement of each individual.

Each of these methods of examination would in all probability give very similar results, and each would be equally accurate when taken over large numbers. But the risk of hardship in individual cases would be very great if either of the first two methods of examination were exclusively employed, and for practical purposes the third method is the only one available, when the intention is to call up men for active service. The third method of examination should, of course, include the first and second to make the report complete.

Judging from the standard of height and weight alone, some interesting figures are given for the West Midland region, comprising Staffordshire, Warwickshire, Worcestershire, Herefordshire and Shropshire. If five of the larger industrial centres in the region are taken—Birmingham, Burslem, Coventry, Walsall and Wolverhampton—and an average is made for these five centres, it is found that the following results are obtained as regards height and weight :—

height at 18 years is	$\frac{7}{8}$	inch below average of general population.
„ 25 „	$1\frac{1}{2}$	„ „ „
„ 30 „	2	„ „ „
„ 40 „	2	„ „ „
weight at 18 years is	$8\frac{2}{5}$	lbs below average of general population.
„ 25 „	$12\frac{1}{3}$	„ „ „
„ 30 „	$22\frac{1}{4}$	„ „ „
„ 40 „	23	„ „ „

These results show that the growth of these recruits was not only retarded, but that the full measure of growth required to bring them up to the standard of the general population was never attained. Rickets is peculiarly a condition which retards growth, and nowhere does healthy environment tell more directly than in growth and stature both as regards height and weight.

In applying standards of height and weight the difficulty arises that there is no accepted standard of physique. In the case of school children the ubiquity of the conditions which react harmfully on the child makes one content with not only a much lower general standard of physical growth, but also with a lower standard of mental development than might legitimately be expected if the environment of the child were such as to allow of its full mental and physical development. Speaking of the disparity in development met with in different social grades of school children, Dr. Kerr very rightly remarks* : " As a nation we should not accept quietly the difference in physique between primary and secondary schools. We must make all our children pass into the one national standard of physique, and no longer regard as inevitable the inferior physique of artisans, and superior of professional classes, knowing that the difference is largely due to social failure and is an index of national inefficiency."

Similarly with recruits there is evidence to show that a combination of height, 5 feet 6 inches, weight, 130 lbs., chest girth, 34 inches, will be found to be approximately the average of the Grade I. men of military age. As the National Service Report points out, it is impossible to regard these standards as satisfactory or to rest content with the economic and social conditions which are responsible for such a result.†

It is a matter worthy of note that nearly all the medical officers reporting on the results of recruiting throughout the country point out the disastrous effects of defective housing and slum areas on the physique of the recruits coming before

* " Standard Measurements for School Children," by James Kerr, M.A., M.D., *School Hygiene*, April, 1918.

† *Loc. cit.*, p. 23.

them. Speaking of the West Midland region, it is remarked that the tendency of industrial life is to lower physical fitness ; men are middle-aged at thirty and old men at forty. " The worst housing," it is stated, " is in the city of Birmingham and some of the large towns, although in rural districts there is also much to complain of. In Birmingham there are many highly congested areas with considerable slum property and a large number of back-to-back houses. At the date of the Poor Law Report these were estimated at forty thousand. In some densely populated wards of the city there is a high infantile mortality, which is indicative of the general conditions which exist there."*

Speaking of Glasgow, the Commissioner for Scotland, as the result of his experience of the examination of recruits, states :—

" The physical characteristics of the male population, on the whole, are not good, the stature being on the small side, and there being an unduly high percentage of physical malformations.

" The industrial classes are housed chiefly in flats, and overcrowding is common. Such conditions necessarily lead to physical deterioration of the inhabitants. The east, north-east and south-west portions of the city are to a considerable extent slums, and consist almost entirely of flats of houses of a relatively small number of rooms, which are badly ventilated, badly lit, and insanitary.

" As one would expect from its size and importance as an industrial centre, the atmosphere of Glasgow is unduly smoky and polluted, and there is in the area more than the average rainfall. These facts, together with the very high buildings and the many relatively narrow streets, account for the lack of sunshine in the quarters occupied by the working people. In such areas there is a notorious lack of suitable air spaces and playing grounds for the young.

" Furthermore, the health-giving recreations of the industrial classes occupying these areas are almost *nil*, their spare time being taken up in parading the city streets,

* *Loc. cit.*, p. 72.

attending picture-houses, and watching certain games instead of taking part in them.

“Such conditions do not encourage the maintenance of good physique or satisfactory health in the present inhabitants, nor give promise of the production of better physique and vitality in the next generation.”*

It is important to bear in mind that there is no evidence of true racial degeneration. On the contrary, allowing for racial differences, there has been a marked increase in stature, both in height and weight, of the inhabitants of England as compared with prehistoric man in Great Britain, or with the early Briton of the Roman period, or even with the Englishman of mediæval times. This is amply borne out by examination of the bones from ancient burial grounds and comparison with average skeletons of to-day. The great improvement in food supply, in quality, quantity and variety, and the greater security that there will be a sufficiency for each day, and not a time of plenty and a time of comparative famine, are probably the main factors bringing about this enhanced stature. But, apart from this improvement in food, the environment has become more harmful, and diseases such as rickets, have arisen which were unknown when, though the feeding was precarious, life was untrammelled by the conditions which now beset modern civilisation. As history goes the growth of towns is an incident of modern life, but, though recent, the conditions associated with industrial communities have proved inimical in a high degree to the welfare of the race. From being rural dwellers employed in agriculture the population has become a nation of cotton spinners, miners, and workers in steel, with an environment which has been peculiarly dysgenic in that it has acted most harmfully on the young infant.

As the war progressed, it became increasingly necessary to employ all available man power, and if a recruit could handle a spade or mount guard it was held that, though not himself able to stand in the fighting line, he still had some function in the army, and could at least take over work

* *Loc. cit.*, p. 128.

which would release more fit men for the trenches. As an aftermath of the war the country has now been faced with a heavy drain on its resources in compensating many of these later recruits for the aggravation of disabilities which existed long prior to the war.

The question as to whether or no a discharged soldier is, or is not, entitled to pension is often a difficult one to decide, but, strangely enough, the difficulty does not arise with the man who has seen active service in France, or who has acquired infection in Salonica or Mesopotamia, but arises rather with the man who was never considered fit for service in a fighting unit, and who was attached to a labour corps, frequently being engaged in camp duty at home or in some such occupation as loading and unloading transports at the base. Large numbers of these men joined up with disabilities of long standing which had possibly existed since early childhood. Such cases merit every consideration, for usually they have been handicapped from their earliest start in life, and it is often a problem which requires great judgment to decide how far these conditions have been affected by military service.

Conditions such as deafness and discharging ears are exceedingly common, and, as stated, have usually existed since early childhood. The association of rickets with enlargement of the tonsils and adenoids is a very direct one, and mouth-breathing and infection of the middle ears form, as has been shown, a common sequence. These men present a characteristic appearance. The lower jaw drops, and the mouth is open, giving a vacant dull expression to the face. Often there is marked bossing of the skull or a heavy overhanging forehead. On examination the man is found to be a mouth breather, and the nose is badly developed and is not used for breathing purposes; deflection of the nasal septum is common, the palate is arched and high, the teeth are carious and irregular, and hypoplasia is common. The face is long, thin and lantern-jawed. The tonsils are probably enlarged and may be septic, and adenoids are, or have been, present. The chest is badly developed, and the breathing

capacity is deficient. Frequently the muscular power is feeble, though in many cases this has developed to a wonderful extent, and there is considerable physical strength. Inquiry into the early life reveals that such a man has been backward at school; the despair of his teachers, he has only left school on account of age, never having passed the fourth or fifth standards. When he leaves school he obtains employment as a van-boy or as an errand-boy, and later on he drifts into casual labour. In after-life he marries, but he has little ambition, and lacks the capacity to create a comfortable home around him. His wages are small because he is of but little value in the labour market. He probably lives with his wife and three or four children in two rooms in a slum area. The mother is badly nourished, and the children are poorly fed, and it is little wonder if his offspring reproduce the same characteristics and develop along much the same lines as the parent.

It is frequently asked what can be expected from the child of such a parent, forgetting that there is not necessarily any inherent degeneracy in the individual, but that he is the product of a vicious circle of environment. He resembles a mentally deficient case, and is frequently, when a schoolboy, referred by his teacher for examination on this ground. He is not, however, a case of true mental deficiency, but is simply an example of obstructed and thwarted development, produced in response to a perverted environment operative since birth. If the children of such a parent are removed in early infancy into airy surroundings and are properly clothed and well fed, experience shows that they develop along normal lines and tend to become bright and intelligent and as physically sound as the average. The influence of heredity will be discussed later, but in the meantime it cannot be too strongly insisted upon that it is the persistence of the evils of the environment which produces the same type generation after generation in the slum dweller, and not inherited disabilities from degenerate parents. It is with this class that the greatest difficulty will be experienced in helping them to find their place in the labour world after

the war. They require much patience and consideration. Teaching them how to fit themselves into the general scheme of labour is much more likely to benefit them than any dole in the form of pension. Above all, the children should be protected as far as possible, and at as early a date as possible, even at the risk of much sacrifice, from the inimical influences which have operated so disastrously on the parents.

All reports on the state of the public health which have been published during the last decade have shown a steady improvement in the health of the community. These favourable reports have been chiefly based on diminished mortality, both infantile and adult, and a lessened incidence of certain diseases.

Caution must, however, be exercised in drawing deductions from mortality tables as to the state of the general health. So much is this the case that there is very little reason to believe that the general health of the community, as measured by the capacity of the individual for work and for the enjoyment of the amenities of life, is better to-day than it was say three centuries ago, and that notwithstanding the fact that plague, typhus and typhoid fevers, small-pox, and other allied states, have for all practical purposes been abolished.

It is true that the conditions which lead to a high infant mortality must also tend to produce disease in many who survive, but this by no means implies that a diminished infant mortality is necessarily followed by a lessened amount of disease in those who survive.

But little notice is taken in health statistics of the standard of health. It is recognised by all that there are certain broad class distinctions, and that the health of the children of the better class of the community is superior to that of the poor and of the industrial class. To be efficient the conduct of public health must concern itself with the attempt to raise the general health of the whole community to the level of what can now be attained by only the favoured few. Even a cursory consideration of the state of retarded mental and physical growth and the general poor level of

health seen in the industrial areas of large towns should be a sufficient safeguard against any undue elation on the score of past achievements.

Observation of such communities shows defective growth, as indicated by coarse features and a large square head, often with overhanging eyebrows. The stature is apt to be stunted, or the individual may be tall and weedy with a flat chest and stooping shoulders. Mental development is often very backward; and the irritable nervous system is peculiarly liable to give rise to convulsive attacks. Anæmia is common, and the complexion is sallow and muddy. Enlargement of the tonsils and adenoid vegetations are frequent, and are apt to be associated with mouth-breathing, discharging ears and deafness, or chronic catarrhal non-suppurative otitis media. The teeth are irregular and defective, and decay early. There is great muscular debility. This wide prevalence of ill-health is the large factor in producing the inefficient adult.

It cannot be too clearly realised that much of the ill-health of the community is the direct result of life in industrial areas in great towns under modern conditions, and that it is in reality but the result of the normal response of the individual to a vicious environment; in other words, these changes are of an adaptive nature, the rachitic process being one of nature's chief methods in bringing this adaptation about.

There are then great numbers of diseased states, and conditions of impaired health, and want of physical and nervous energy, which fail to find their place in any health tables. And yet it is to these conditions that the inefficiency of the nation is primarily due.

Rickets is one of the chief agents concerned in the production of these impaired states. A hopeful feature is that these conditions are capable of great amelioration, and have indeed already been much improved by the intelligence of an enlightened motherhood, which has been quick to seize on some of the broad essentials which have been proved efficacious in the bringing up of the infant and young child.

CHAPTER XXVI

The *Ætiology* of Rickets

It is one of the great qualities of the mind of John Hunter that, while he studied inductively and based his work on experiment and observation, he was still able to preserve the magnificent detachment which belongs to the deductive mind and, looking beyond mere detail, to formulate great generalisations capable of the widest application.

Hunter propounded the theory that disease was but the physiological response of an organism to an environment which demanded alteration of development or modification of function or structure to meet conditions to which the healthy organism could not normally respond. In other words, he believed that there was no hard and fast line of demarcation between health and disease or between physiological and pathological processes. Each alike was the effort of the organism to respond to the actual conditions which surround it. It is a notable fact that many diseases are a result of the infraction of the simplest laws of health and a neglect of the most obvious rules of right living.

Alteration in environment may be of two kinds. First, there may be an actual alteration in the external surroundings, such as change of diet or of climate, or an alteration in the habits of the race to which the organism must adapt itself. Or, secondly, there may be a relative change of environment due to an alteration in structure and function of the organism itself. Thus a hereditary disease, such as congenital syphilis, profoundly alters the relationship of the individual to its surroundings, leading to widespread changes which have, as already noted, a peculiar resemblance to those associated with rickets. One important difference, however, is that while the adaptive efforts of the victim of

syphilis are frequently unsuccessful, so that death, either ante-natal or soon after birth, is exceedingly common, in rickets the disease in itself does not as a rule end fatally, but results in recovery more or less complete. Possibly the difference is that in syphilis the child itself is diseased and is combating a comparatively normal environment, whereas in rickets the child is normal except for the effort it is compelled to make to suit itself to a vicious environment. In the rachitic child the cause in any individual case is capable of being easily removed, and the child tends to return to the normal.

Rickets is a morbid process which will be better understood if it is considered as the sum of the results achieved by the organism in attempting to adapt itself to altered environment. The parent is exposed to extreme alterations of surroundings to which the adult organism is capable of making a ready response. The infant *in utero* is screened from the varying conditions which surround the parent, so that, broadly speaking, it seems to make little difference whether the new-born infant comes from the dweller in the slums or is the child of the wealthy. Both alike seem to start with equal chances of healthy growth. A few months later it would seem as if the weakly, rickety infant were the natural product of the badly developed, overworked, and, it may be, underfed parent, but, as a matter of fact, it is found that if the child is taken from its unhealthy environment and placed in wholesome surroundings it immediately responds to the altered conditions and tends to become a healthy normal individual. Nothing is more important in rickets than this constant tendency to spontaneous recovery. In other words, it is not necessarily an inherited tendency which makes the child of the slums resemble its weakly, degenerate parents, but is more commonly the fact that both parent and child are born and brought up under similar adverse conditions, inimical to all healthy growth and maintenance.

Of late years the great contention as to the ætiology of rickets has lain between two factors, deficiency of food and faulty environment. Rickets is a disease of nutrition, and

it is natural in the first instance to consider the question of food supply. This has given rise to several crude theories which are readily proved untenable.

Most of the earlier theories supposed that some disturbance of the calcium intake was responsible for the production of the disease, which might be produced in various ways.

Lactic Acid Theory.—This theory maintained that lactic acid was generated in excess by the fermentation of starchy foods imperfectly digested. By its absorption into the circulation the acid was held to unite with the lime of the bones, forming a soluble salt which was removed from the system. This hypothesis, like many others, is founded upon a supposition that the morbid changes in the bones comprise the whole pathology of the disease. It affords no explanation of the morbid processes which affect the muscles, tendons, mucous membranes and the special organs. Heitzman held that lactic acid produced an irritating effect on the ossifying tissues and stimulated growth, while the material necessary to complete growth was wanting. Lactic acid is said to have been found in the urine and in the tissues of rickety animals, and Heitzman claimed that he had produced the disease in animals by its administration. This increased formation of lactic acid has not been confirmed,* and while acid food may produce a disease in which the epiphyses and the costo-chondral junctions are enlarged and in which the bone is easily broken, the results are comparable to those found as the result of feeding on a calcium-poor diet, and are due to the same cause. The lactic acid theory is open to objection on chemical grounds, for it obviously could not exist in the blood in a free state, but would be neutralised by soda or potash. Again, if it were present in the blood, lactic acid, being more feeble chemically than phosphoric acid, would not replace it in phosphate of lime. Many children, too, become rickety without any evidence of fermentation dyspepsia and on malted foods and condensed milk which they digest perfectly.

* "System of Medicine," Allbutt and Rolleston, London, 1907, Vol. III. p. 84.

Calcium-poor Foods.—Frequent experiments have been performed on animals with diets deficient in calcium, and very varying results have been obtained. Usually animals fed on such a diet or on an acid food, which comes into the same class, develop disease of the bone, which in gross appearance resembles rickets. Great care has, however, to be exercised in the interpretation of such experiments. Dogs under experiment are especially liable to the development of bone changes, and such detached laboratory experiments as a rule make no pretence to align themselves with clinical experience. In the case of animals fed on calcium-poor diets, Miwa and Stoeltzner * found there were certain differences between this artificial disease of the bone and true rachitis as described by Pommer † in 1885. Pommer defined for the first time the essential nature of the bony changes which occurred in rickets. These were the formation of osteoid tissue, increased and irregular cartilage growth, associated with delay in calcification and delay in ossification. The framework laid down was largely composed of non-calcified osteoid tissue.

Miwa and Stoeltzner found that there was but slight disturbance in the endochondral ossification and a very considerable osteo-porosis. Stoeltzner, therefore, named the condition pseudo-rachitic osteo-porosis. This pseudo-rachitic bone possesses a marked affinity for calcium salts, and takes them up as soon as they are supplied.

These results were confirmed by Götting ‡ and Schmorl. § Admitting that changes in the bones resembling those of rickets can be produced experimentally by the exhibition of a calcium-free diet, there is abundant evidence to show that

* Miwa and Stoeltzner, " Ueber die bei Jungen Hunden durch kalkarme Fütterung entstehende Knochenerkrankung," *Beitr. z. path. Anat. u. allg. Path.*, 1898, XXIV., 578.

† Pommer, " Untersuchungen über Osteomalacie und Rachitis," Leipzig, 1885.

‡ Götting, " Ueber die bei jungen Tieren durch kalkarme Ernährung und Oxalsäurefütterung entstehenden Knochenveränderungen," *Virchow's Arch. f. path. Anat.*, 1909, CXC VII.

§ Schmorl, " Die pathologische Anatomie der rachitischen Knochenkrankung mit besonderer Berücksichtigung ihrer Histologie und Pathogenese," *Ergeb. d. inn. Med. u. Kinderh.*, 1909, IV., 403.

this is not the common cause of rickets in children. In the first place, rickets is exceedingly common in the limestone districts, where the ordinary drinking water is heavily charged with lime.* Many children who develop the disease have had lime water regularly in their food. Again, the very foods upon which children are supposed to become rickety, such as farinaceous foods, are rich in lime and in phosphoric acid, and cow's milk is richer in these than is human milk. Not only does the abundant supply of calcium salts not prevent the development of rickets, but the disease is usually developed while abundance of these is being supplied. Neither excess of carbohydrates nor deficiency of calcium will in itself produce rickets, and it has frequently been shown, that when the conditions of the child's life are altered, there is rapid improvement on precisely the same diet as that which was supposed to have caused the disease. In some recently published experimental studies by Leonard Findlay, D. Noel Paton and J. S. Sharpe,† the work of Stoeltzner has received confirmation. These authors come to the conclusion that changes in the bones simulating somewhat those in rickets can be caused by feeding dogs on a calcium-low diet, but that the condition is of the nature of osteoporosis and not true rickets. As a result of their observations they find that no support can be given to the view that rickets is due to a deficient supply of calcium to the bone; the disturbance in the calcium metabolism is probably not the primary factor in the disease. While the lime theory has been largely discredited, other more important deficiencies have been blamed for the production of rickets.

Deficiency of Proteids and of Fats.—It is somewhat strange that attention has for many years been directed to the shortage of fats, and that deficiency of proteids has been comparatively little dealt with. Now in the children of the poor there can be but little doubt that insufficiency of proteid

* "A Discussion on Rickets," W. B. Cheadle, *British Medical Journal*, 1888, Vol. II., p. 1146.

† "Studies in the Metabolism of Rickets," by Leonard Findlay, D. Noel Paton, and J. S. Sharpe. *The Quarterly Journal of Medicine*, Oxford, Vol. XIV., No. 56, July, 1921.

supply is the outstanding failure in their diet and is probably a large factor leading to imperfect development and impaired growth. The human body is chiefly composed of albuminous or nitrogenous substances, and in the metabolism of these bodies the source for most of the functions of the body is found. The albuminates or proteids of the food have three main functions. In the first place, they are the chief agents utilised in the repair and development of the nitrogenous organised tissues ; secondly, they stimulate functional activity and promote oxidation and metabolism ; thirdly, they are capable of being split up and of contributing to the formation of fat and to the development of muscular and nervous energy as well as to the production of heat.

Very noteworthy is the remarkable effect meat extracts have on the general nutrition. It has repeatedly been proved experimentally that the addition of beef extracts in small quantities to the diet of wasting animals improves the nutrition of the animal out of all proportion to the volume of the intake of the extract. Clinically the same is found in the feeding of infants and children. In other words, the process of assimilation is stimulated, and the general metabolism is improved. Raw meat juice and scraped meat are most useful additions to the diet of the rachitic child, as, indeed, they are in most wasting diseases of children.

A moderately healthy child may be reared with the use of little or no meat, but the best results are not obtained by such a diet. When the diet is so restricted, the child will not attain the same height and weight as a child fed on a diet in which meat is an important constituent, nor will it have the same physique and mental energy, while it tends to be much less resistant to infection. In the feeding of children all eccentricities of diet should be carefully avoided. A diet, to be perfect, should be well balanced, and this is best attained by throwing the net as widely as possible and utilising all the various articles of food consistent with a simple and wholesome fare. It is easy to exaggerate the degree to which the children of the poor suffer from insufficient diet. Many go to the other extreme, and say that rickets is due to

an over-abundant supply of food and the failure of the organism to deal with an excessive intake, more especially of carbohydrates. No one, however, who examines carefully a thousand children from slum areas, would maintain that excess of diet, whether well balanced or no, is a factor which is commonly operative. Many of them are obviously underfed, but the percentage is not so great as is usually supposed. Among the children of the East End of London the nutrition is on the whole very fair, and in certain schools, as already noted, in 80 per cent. the nutrition was either good or very good. Rickets is equally common among well-fed and badly fed children, but in the former it tends to run a modified course. The point has before been insisted upon that with the most perfect breast feeding, if the child is exposed to certain conditions, it will inevitably develop rickets.

It must be remembered that rickets appears at a time when the child is normally at the breast and is independent of the general table. The percentage of breast-fed babies among the poorer classes is very high, approximating, as has been seen, to 80 per cent., and yet in certain areas of all large industrial towns practically all the children show signs of rickets of a more or less severe form. The question naturally arises as to whether or no the quality of the mother's milk is at fault in these cases. In the majority, the nutrition and state of the mother's health is on the whole good. A careful examination by means of test feeds where the child is weighed immediately before and after being suckled shows as a rule that the intake is sufficient. It is not often that breast feeding has to be given up on this account.

Indeed, failure of the milk supply is more likely to occur among well-to-do mothers of the middle and upper classes. Among the poor the child is more often weaned because it is obviously not thriving at the breast, and that in spite of the fact that the mother herself is in good health, and the supply is not insufficient.

The deficiency of fats has now for many years been considered the chief factor in the production of rickets. This

has largely been based on the value of fats in the treatment of rickets. One of the great purposes served by fat in the food is to diminish albuminous metabolism.

Proteids and fats are to a certain extent opposed to one another, in so far as the former increase waste and promote oxidation, while the latter have the power of diminishing these processes, and this they do by affecting the metabolic activity of the cells of the tissues themselves.* Fat, therefore, economises the albuminous elements of the food and checks tissue waste, while by its decomposition it yields muscular force and heat.

Rickets always markedly affects the tissue proteids, and as a result the muscle fibre throughout the body tends to become wasted, soft and flabby. If the disease is at all marked, the child lacks energy and avoids the active movement which the normal child rejoices in.

Very commonly in rickets the child tends to become thin, and the subcutaneous fat wastes. The fat disappears rapidly, and at an early stage, from the yellow marrow of the shaft of the bones, and is replaced by a proliferation of the medullary cells. But this wasting of the fatty constituents of the body is by no means a necessary part of the rachitic process. There is a large and well-recognised class of children which suffers from "fat" rickets. Frequently in these cases there has been difficulty with the feeding. Breast feeding may have been abandoned because the child was not thriving, and after many experiments condensed milk may have been found to suit the child. Condensed milk is often useful in tiding a child over a temporary difficulty. The sweetened variety commonly used contains 13 per cent. of fat, that is to say all the original fat of the milk, besides considerable quantities of added sugar. The milk is given so dilute that the curd which is formed is very light, and the milk is easy of digestion. The child appears to thrive and often has a false appearance of health because it lays on a rapid deposit of fat, and a stolid, heavy child results, with flabby muscles, in whom the disease is not suspected till it is found that by

* "Food in Health and Disease," by I. Burney Yeo, London, 1893.

the twelfth month the child has not cut any teeth, or that by the end of two years it has made no attempt to talk or to walk. The rickets is usually attributed to the use of the condensed milk without any very valid reason. There is no evidence of this, for the food is exceedingly well digested, nor is there any want of fat in the ordinary brands used, for they contain all the original fat of the milk. The truth is that the milk has no power to produce the disease, nor is it able to prevent its occurrence if the infant is exposed to the ordinary conditions which produce rickets. Malt and cod liver oil and fat emulsions are frequently given to these children in excess, and at the same time they are kept indoors and are deprived of exercise and fresh air. They become heavy and stolid; a want of colour is noted in the face, and the mucous membranes are pallid. The muscles are soft and flabby, and the ligaments lax and weak, and the child generally is lethargic and dull. Thus, while emaciation is often present in rickets, it is by no means invariably so.

The Vitamin Theory and Experimental Rickets in Animals.—The development of the vitamin hypothesis of late years has given rise to the theory that rickets is due to an absence of fat-soluble A or of some factor which has a similar distribution. In speaking of food in relation to the geographical distribution of rickets, the subject of deficiency diseases has already been referred to. It is now fairly generally accepted that beri-beri is a condition due to the absence of an accessory food factor or so-called vitamin, the anti-neuritic factor which is probably identical with water-soluble B. Similarly scurvy and Barlow's disease in children are now considered as definitely due to the absence of the anti-scorbutic factor from the food. By analogy it has been suggested that rickets is another such disease and is due to the absence of an accessory food factor associated with fats.

In 1910 Schaumann suggested that rickets was due to the lack of a specific food factor, and somewhat later Funk included it among the avitaminosen.

Recently Dr. and Mrs. Mellanby* have carried out some experimental work on the ætiology of rickets, and have supported the view that the disease is due to the absence of fat-soluble A or an associated factor. As a result of experiments on dogs, these observers maintained that animals fed on diets deficient in the supply of suitable fats, developed extensive and well-marked disease of the bones and teeth, while diets containing abundance of the so-called anti-rachitic factor, such as is present in cod-liver oil, effectually prevented the disease. The efficiency of the various oils was found to vary greatly, vegetable oils being generally less active than animal fats, while among the vegetable oils themselves great differences were found in the quantity of the anti-rachitic factor. One peculiar result found was that lard contained no anti-rachitic factor. Clinically bacon fat is a most excellent way of administering fat to poorly nourished children, and it is usually well digested. There is no question of the extensive disease of the skeleton and teeth produced in these animals. Indeed, the whole growth of the animal seemed to end in a complete *débâcle*, so that of the two hundred animals experimented upon many died, while those which survived developed, in the course of a few weeks or months, extensive softening of the bones associated with bending and deformity. The temporary teeth were frequently mere shells of enamel imperfectly calcified with some defective dentine and a large and expanded pulp cavity. The whole condition was of a degree of intensity the like of which is never found in children. It may be argued that the rapid development of the puppy, as compared with the slow growth of the child, would naturally lead to an acute process. This is true to a limited extent, but it also opens up the avenue to many other complications. Dr. Mellanby himself states that the rachitic condition need not be at all advanced before the animal's whole behaviour is transformed. It becomes lethargic, and is far more liable to

* "An Experimental Investigation on Rickets," by Ed. Mellanby, *Lancet*, March 15th, 1919; "An Experimental Study of the Influence of Diet in Teeth Formation," by May Mellanby, *Lancet*, December 17th, 1918.

be affected by distemper and broncho-pneumonia, and is very susceptible to mange. Nor do the results as propounded by Dr. Mellanby warrant the assumption that rickets is due to the absence of fat-soluble A or a definite factor associated with it. It was found that meat itself had a powerful action in the prevention of rickets. Dr. Mellanby states, "The action of meat is undoubtedly inhibitory in nature, and when fifty grams of meat are given will almost prevent rickets in a growing puppy. Meat has a stimulating action on the growth of puppies far beyond its fat-soluble A content, so also it appears now that the anti-rachitic action of meat is in a greater measure than any fat-soluble A it is reputed to contain."

Recently Professor Noel Paton has published some experimental results which directly contradict the conclusions arrived at by Dr. and Mrs. Mellanby.* It was found that in young dogs confined to the laboratory under ordinary conditions a liberal allowance of fat, even up to fourteen grams per kilogram of body weight, neither prevented the onset of rickets nor cured it when present. On the other hand, pups kept in the open air, even on an intake of less than one gram of fat, might escape the development of rickets.

A very interesting observation is made as to the necessity of observing strict cleanliness where it is desired to prevent rickets. Three litters of pups were placed on varying diets, but each diet was so arranged that it increased proportionately to the increase of the animal in weight, and care was observed that the energy intake in each case should be kept ample throughout the period of growth.

One series was placed on fresh whole milk and bread, another on dried whole milk and bread, a third on dried separated milk and bread, and in a fourth lard was the only fat used, a fat stated by the Medical Research Committee to be deficient in the so-called anti-rachitic factor.

All of these animals were kept in the laboratory, but scrupulous care as to cleanliness was observed throughout

* "The Etiology of Rickets: an Experimental Investigation," by D. Noel Paton, M.D., F.R.S., and A. Watson, *British Medical Journal*, April 23rd, 1921.

the experiment. The result was that all the pups, with one exception, remained free from rickets, although those upon the separated milk and bread had only from 0.3 to 0.6 gram of milk fat per kilogram of body weight each day. This observation as to the necessity of observing strict cleanliness is borne out by experience in sporting kennels. It is a matter of interest in relation to Kassowitz's belief that the continuous inspiration by the young infant of exhalations from soiled clothing was a fertile source of rickets. In these experiments then it was found that under ordinary conditions all animals confined to the laboratory tended to become rachitic, but when scrupulous cleanliness was observed the disease was prevented. In the open it was found that it was difficult to produce rickets. In none did the presence of fat prevent the onset of the disease when the other conditions were favourable to its production, nor did its absence produce the disease when the animals were allowed to run free in the open.

Two other facts are emphasised in Professor Noel Paton's results: firstly, that a diet of low energy value, however plentifully supplied, quite apart from the presence of any hypothetical anti-rachitic factor, may render the animal more liable to be attacked by rickets. This does not imply that it is caused by such a diet. On the contrary, if the animal is placed on a high energy intake while it is kept in the laboratory under ordinary conditions, rickets results. The second point is that the supply of fat in the form of lard is quite efficient for the maintenance of normal health and growth. This is an important matter, which agrees with all clinical experience.

The whole question of experimental rickets is a difficult one. Dogs are known to be notoriously prone to rickets. In artificially bred dogs, such as the bull-dog, it is exceedingly difficult to prevent rickets. No matter what food is given to a bull-dog pup, if the animal is placed on a hard stone floor, it will inevitably develop severe rickets. With sporting dogs the hygiene of the kennel is the first essential if the health of the dog is to be maintained. Fresh air,

sunlight, proper exercise, and scrupulous cleanliness are found necessary. Bland-Sutton's early observations on lion cubs at the Zoological Gardens in London, whereby the addition of fats and crushed bones to the diet of the cubs allowed some of them to be reared, have gained wide credence for the view that fats prevent rickets. But this knowledge has by no means abolished rickets from the Zoological Gardens. Sir John Bland-Sutton states that systematic inquiry which he has conducted into the diseases of animals dying in the Zoological Gardens, has established the fact that rickets is a very common disease, and that half the monkeys and lemurs brought to this country die rickety. He gives the following extensive list of animals he has found suffering from this disease :—

among the carnivora.—Lions, tigers, hyænas, bears of all kinds, domestic cats, dogs, foxes, racoons and seals ;
among ruminants.—Deer, sheep and goats ;
among rodents.—Beavers, porcupines, rabbits and coypu rats ;
among marsupials.—Kangaroos, phalangers and opossums ;
among birds.—Emus, ostriches, rheas and pigeons.

That rickets is exceedingly common in the young of animals born in captivity is undoubtedly true, but there is a large margin of error, if every animal dying in captivity and exhibiting bony changes associated with softening and bending of the long bones, is to be considered rachitic.

I have recently had the opportunity of examining the skeleton of a chimpanzee which died at the Zoological Gardens with extensive disease of the skeleton. The animal was eighteen years of age when it died, and had been in captivity for six years. It was ill for three or four years. All the bones were very light. The head of the humerus on each side was much flattened, and was depressed, resembling the condition that in the hip joint is called coxa vara. There was extensive osteo-porosis and much bending of the bone. Similarly the tibia was markedly distorted in its upper third, and the bone was very light and porous. The femora were light, but were not notably deformed. No attempt at consolidation or repair had taken place in the long bones.

The bones of the skull, especially in the frontal region, were greatly thickened, and consolidation had taken place to a considerable extent, for the texture of the bone was compact, and the skull was heavy. But the most marked changes were in the bones of the face, especially of the superior maxillæ, which were enormously enlarged and thickened, resembling very closely the appearance found in leontiasis ossea.

This enlargement of the bones of the face is a fairly common feature in so-called experimental rickets. Such a massive overgrowth of the superior maxilla never occurs in the rachitic state in children, although, as has been already noted, a slight degree of thickening of the bone sufficient to produce a shadow on transillumination is not so very uncommon. Characteristic changes occur in the jaws of the child, but they are never of the extreme kind so often found in experimental rickets and in animals in confinement. It will be noted that the disease attacked this animal after it had reached the adult stage, and consequently the structure of the teeth was unaffected. From the history and from the nature of the bony changes, I have no hesitation in stating that the condition was not one of rickets. The term "rickets" is loosely applied to all softening of the bones which occurs in animals in confinement and in the laboratory, but the probability is that many of them, as in the case described, have a pathogenesis quite different from that which occurs in true rickets.

The vitamin theory is wholly inadequate as an explanation of the strong tendency which the young of all animals kept in captivity show to the development of spontaneous rickets. In the wild state these animals never develop the disease. Contrast the life of the lion cub or of the young of the tiger in its wild state with what appertains in confinement. In its wild state soon after birth the animal plays in the sun. It ranges over all sorts of ground, now on stone, now on sand, or again in mud or shallow water. Every encouragement is given to the development of all its physical energies. Its food, as with all beasts of prey, must be subject to severe variations, but rickets never results. In captivity

the young animal is confined in a small space on a hard cement floor. The food is served in abundance and regularly. The metabolism of such an animal is enormously rapid, and it seems more reasonable to attribute the defective growth which occurs to the altered conditions as regards fresh air and sunlight and exercise, and the loss of the varying environment of the young animal in its wild state, rather than to the food factor which is all in favour of the animal kept in captivity.

While this spontaneous disease in the young animal is probably a true rachitic process, there is a very large doubt whether or no the type of bone disease produced experimentally is true rickets. The results of experiments on animals are exceedingly conflicting.

Experimental work in the production of rickets has been carried out by many observers. In 1838 Jules Guerin shut up two dogs in confinement and fed them on bread and meat, and at the same time allowed some control dogs to run in a park while fed on the same diet. At the end of three months both series of animals had developed diarrhoea and suffered from rickets. As a result, Guerin maintained that defective alimentation and premature weaning were the essential causes of rickets.

In 1864 and 1874 Leon Tripier sought to confirm these results, but failed and came to the conclusion that neither defective alimentation nor premature weaning had anything to do with rickets.

Troitzky * in 1896 fed dogs on a potato broth and gave daily laxatives and found that in three months the animals presented the signs of the disease in a rachitic rosary, bending of the long bones, dental caries and wasting. Microscopically, however, the bony changes did not conform to those found in true rickets.

L. Spillman experimented on lambs, cats, chickens, rabbits and a young fox, submitting them to varying conditions of bad hygiene, defective alimentation and premature weaning. As a result, he found that all these conditions

* Troitzky, Société des médecins Russes, Congrès de Kiew, 1896.

produced digestive troubles, diarrhoea, arrest of growth and wasting. Only rarely did he find osseous lesions, and when they were present they did not present the appearance of rickets microscopically.*

Most observers are now agreed that there are wide differences between so-called experimental rickets and the human form of the disease. That a true rachitic process does occur spontaneously in young animals as the result of confinement is probably true, but that there are other forms of bone disease to which animals in captivity are liable seems almost certain.

In captivity, it is quite clear that it is not the food which is at fault. It is a matter of common observation that the young of all species delight to skip and jump and frolic in the open, and that free and unrestrained movements are necessary for the maintenance of health and the process of growth. Stock breeders, especially of the heavier varieties of stock, are well aware that unless the young are allowed their liberty soon after birth they do not thrive, the joints become thickened and the legs are clumsy and heavy.

On the other hand, bulldogs, some years ago, were frequently kept chained up so as to produce the outward bend of the legs considered desirable, for breeders knew that free exercise in the open tended to produce straight limbs. Rickets most frequently attacks the heavier or lymphatic type of dog, such as the Great Dane, St. Bernard, wolfhound, bloodhound and foxhound. The difficulty of keeping kennels of sporting dogs free from rickets, even when the feeding is excellent, has already been referred to.

In many ways, experimental rickets differs from true rickets and resembles osteo-malacia. The experimental disease, like osteo-malacia, often tends to assume an epidemic form, and frequently spoils whole series of experiments. It affects the adult animal as well as the young. Growth is more rapid in the young of animals than in man, and therefore the experimentally-produced disease is much more acute and frequently tends to produce a complete break-

* Marfan, *loc. cit.*, p. 494.

down of the metabolism and a widespread infection ending rapidly in death. In man, rickets is essentially slow and chronic and constantly tends towards spontaneous recovery. In the experimental condition the absolute and relative calcium content in both the bones and in the soft parts of the body is greatly reduced. This condition is also found in osteo-malacia. In true rickets, while the calcium content of the bones is smaller, that of the soft parts is either greater, or, at all events, not less than normal. There seem, then, to be many varieties of disease in which changes occur at the growing ends of the long bones and also in the membrane bones.

That the young of wild animals are free from rickets in their natural state and that they are subject to rickets in confinement seems to be undoubtedly true. Changes resembling rickets are present in animals kept on a calcium-free diet, but the histological appearances show considerable variation from what are found in the true disease; in the experimental condition the osteoid tissue seems hungry for calcium and takes it up readily when offered, with the production of normal bone. In true rickets there is a failure of calcification even although there is abundance of calcium in the blood.

Scurvy, as has been shown, produces changes at the ends of the long bones resembling rickets.

Acute infections are very apt to mask the rachitic state in experimental rickets and a complete breakdown of the whole development of the animal is produced. Such a condition has little in common with true rickets, which typically leads to a simple delay in development with increased preparation for the normal process but inadequate performance on the lines laid down by Pommer. (See p. 400.)

In the adult animal bony changes which occur in confinement have probably nothing in common with true rickets, and suggest rather some profound toxæmia following an infective condition.

Findlay, in an important article on the ætiology of rickets, lays great stress on lack of exercise as a factor in

the production of experimental rickets.* Dogs deprived of exercise developed the disease while those which had light and fresh air and freedom of movement escaped. Experimental animals, he noted, often developed rickets simply through being caged. Other animals fed by Findlay on foods usually blamed for the production of rickets died from marasmus but did not develop rickets. This agrees with the clinical observation that children suffering from marasmus do not develop rickets. Findlay further points out that during the spring the dispensaries are full of rachitic children as the result of the winter confinement.

Hess and Unger, who have carried out much important investigation on the accessory food factors, at first considered that among the negro women in New York, whose breast-fed children are practically always rachitic, the diet was often deficient in fat. In his recent work on scurvy, Hess, who has carried out much pioneer work in deficiency diseases, has abandoned this view, and, commenting on Dr. Mellanby's work, states "our experience is that rickets develops in infants even when the diet contains adequate fat soluble vitamins." †

* "The Ætiology of Rickets," by Leonard Findlay, *British Medical Journal*, 1908, Vol. II., p. 13.

† "Scurvy, Past and Present," by Alfred F. Hess, M.D., Philadelphia and London, 1920.

CHAPTER XXVII

The *Ætiology of Rickets* (*continued*)

The Ætiology of Rickets considered in relation to the Geographical Distribution.—It has been shown that rickets prevails in a well-defined strip running across Europe and North America between the latitudes 40° and 60° North, that is, a line running approximately through Rome on the south and the north of Scotland on the north. Outside this zone in the rest of the northern hemisphere, and in the whole of the southern hemisphere including this corresponding zone, the disease is almost negligible except, as has been shown, in the case of Australia.

The characteristics of this area have already been discussed. It is wet and damp and is exposed to long, cold winters on the one hand, but, on the other hand, it is the wealthiest section of the globe, and into this zone are poured all the foodstuffs of the earth in abundance. The food of the people is richer and more varied and more uniformly distributed than in any other part of the globe. Yet, with these advantages, Hess states, and his statement is supported by many observers, that within the temperate zone the majority of infants suffer from rickets to some degree.

Breast feeding is still the general rule, especially among the poorer sections of the community, where rickets is most rife. Difficulty in suckling is much more common among the upper classes, where rickets is less frequent and slighter in degree when it does occur.

In England, Scotland and Ireland it has been shown that the prevalence of rickets follows the coal mining and industrial areas. And yet the families of the miners are prosperous and live well on a wholesome and varied diet. The wife does not, as a rule, require to go out to work, and the

fathers, from the recruiting point of view, gave the largest proportion of fit men to the army during the late war. And yet it is in these areas that the disease is most prevalent.

It has already been noted that these same areas of greatest prevalence of rickets, which correspond with the coal fields, are also the areas which suffer from the highest child mortality. It is impossible to ascribe these results to deficient and defective feeding, for these families live exceedingly well. It is little to be wondered at that, in order to keep up the efficiency of the labour supply in the mining districts, it is necessary that it should constantly replenish itself from the country and from the families of the farmers.

In the west and south-west of Ireland, where poverty has prevailed for generations and the people live largely on starchy foods, rickets is, nevertheless, conspicuously absent.

In South Africa the climate up-country is as healthy as can be found anywhere in the world, but it is trying to the nursing mother on account of the great heat and the continued droughts which sap the energies of the white population. Dairy produce is scarce, and the fare is both scanty and coarse, consisting chiefly of bread, meat, and coffee. Milk and eggs and green vegetables are scarce. The child has frequently to be weaned prematurely, and the difficulties of feeding are often great. The addition of starchy foods to the diet at an early date in addition to the breast feeding is exceedingly common. Diarrhœa and dysentery, often of an intractable kind, are frequently present. Yet in these children rickets never develops.

The natives are composed of many races. The so-called Hottentot population of Cape Colony, who form the domestic servant class, the Kaffirs and the Zulus of Natal practically never show signs of rickets. The servant class, who have an admixture of white blood, live on much the same class of food as the white population, but they live mostly under native conditions in the locations outside the towns. The Kaffirs are large meat-eaters, but they also live on coarse grains, such as Indian corn, and sour or fermented milk is freely used when it can be obtained.

In America these same races suffer excessively from rickets, so that nearly all observers agree that it is practically universal among negro infants. The type of disease is often very severe.

Professor A. E. Jenks, the American anthropologist, estimates that one in ten of the population of the United States is negro. He believes that two movements are taking place—one of segregation in the Southern States and in some of the larger cities, while in the north there is a tendency to amalgamation of white and black, especially with some of the more recent European immigrants, among whom the distinction between black and white is not as strictly drawn as it is in the Southern States of America, or in a country like South Africa, where the line of demarcation is very rigid. The study of the physical, mental and moral characters of these people of mixed ancestry is obviously a matter of much importance in considering the development of the population as a whole.

America is not a country where even the poor feed badly, nor can it be said that the native women are worn down by excessive toil. Some cause quite other than the food factor is at work. In Jamaica, as has already been detailed, only 2 per cent. of the population is white, and the children are often weaned early and are usually fed from an early date on starchy pap, and yet rickets is practically absent. The food conditions here are such as are usually blamed for the production of the disease in Europe.

The Italians in London are a thrifty people who cook well and live on a fare more substantial and varied than that on which they subsist in Italy, and yet in London the infants suffer markedly from rickets, and that in spite of the fact that the great majority are breast fed.

The Jews in the East End of London live on excellent food into which oil enters very largely. The health of the mothers is very good and, as has already been shown, over 80 per cent. breast feed their infants. Yet in spite of these facts, rickets—contrary to what is usually believed—is exceedingly common among the Jews, just as common, in

fact, as among the non-Jewish population, but the type of disease is less severe.

Among the great rice-eating populations of China and India, and the East generally, the population lives on a diet of low nutrient value, the proteid and fat content being conspicuously low. The diet is monotonous, and even this simple fare is by no means constantly ensured, for they live at all times on the border line of want. Early admixture of starchy pap with the breast feeding is constantly employed. Prolonged lactation is the rule—indeed, every known dietetic error in the rearing of the infant to which rickets is attributed in England is exceedingly prevalent all over the East, and yet the children do not develop rickets. Probably if Bengali children living in Calcutta under conditions of European housing were systematically examined slight degrees of rickets would be found to be present in some cases. I have had no personal opportunity of making such observations, but crèche workers inform me that in Bengal cases where the child is not thriving and the wrists are slightly swollen are not very uncommon. That does not alter the fact that, taken over India generally, those living under native conditions are entirely free from the disease.

All over India child mortality is high and gastro-intestinal infections are exceedingly common and difficult to combat, but rickets does not supervene. Marasmus and widespread and devastating famines are common and yet the disease remains absent. Obviously over a large portion of the globe's surface, food conditions and errors and defects in diet have no influence whatever in the production of rickets.

During the war over a prolonged period there was a great shortage of food, and substitutes and preserved foods were used to make up the scanty ration. Probably the deficiency was felt more keenly in London than anywhere else. The supply of meat and dairy produce, and especially of fat, was very restricted. The results, however, were quite different from what might have been expected under such circumstances. The general nutrition of school children

both in London and elsewhere was very good, and was, indeed, believed by many medical officers to be better than before the war. There was certainly no formidable outbreak of rickets either in infant welfare clinics or in school clinics, beyond what occurred in ordinary normal times of prosperity. Several factors probably contributed to this result. The head of the family was in the army, but the mother was allowed a substantial sum for maintenance. There was a more equable distribution of foodstuffs throughout all classes of the community owing to the rigid system of rationing.

In spite, however, of the fact that the nutrition was well maintained, there was a large rise in the incidence of tuberculosis, mainly affecting women and children.

The Ætiology of Rickets considered in relation to the Historical Evidence.—Glisson, as has been shown, believed that the essential cause of rickets was to be found in an abundance of rich foods and excess of luxury operating in both the parents and through the parents on the child, and over-nutrition and undue pampering of the child itself. It must be remembered that in Glisson's time rickets, as is often the case with a comparatively new disease, seems to have been of a severe type, and was by no means confined mainly to the poor as it is to-day. Indeed, Glisson's belief, and the general impression of the lay public, was that it affected mainly the children of luxurious homes.

It is evident that in many ways the children of the wealthy in these ruder times had to struggle through a phase of their existence handicapped by adverse features which did not affect the children of the poor. It must be remembered that child mortality was very heavy. Recurring plagues, smallpox, and other epidemic and endemic diseases, created an impression on the public mind which led to excessive precautionary measures which defeated their own end. Sanitary science was unknown, and diseases were attributed to some dread miasmatic contagion from which delicate young life must be protected at all costs. These diseases, it was held, were carried through the air, especially

the night air, and it was therefore deemed necessary that young infant life should be effectually protected from the ingress of fresh air into the nursery. Artificial feeding and milk substitutes did not exist. In wealthy families the child was breast fed either by the mother or by a wet nurse. The resources of the nursery extended no further. The child was shut up in a room which as far as possible was sealed so as to exclude ventilation. Cradles were solid structures, and clothes were heaped on the unfortunate infant while the child was placed near a great fire. In the winter time such a child would hardly be allowed out of the room. Indeed, we have hardly left the old superstition as to the danger of fresh air behind us to-day, especially in the country and among the poorer classes of the community. Certainly up to mid-Victorian times bedsteads with heavy hangings which were carefully drawn at night were in common use. Long sand cushions were placed on the ledges of the windows and at the doors to prevent the ingress of draughts, and are still in use in many homes throughout the country. It is but little to be wondered at that many children, as John Evelyn suggests in the case of his own son, succumbed to the very excess of care devoted to them by the anxious parent and nurse.

Glisson instances the following factors operating in the parents as agents predisposing to the production of the disease :—

- (1) the soft and loose and effeminate constitution of either or both parents ;
- (2) an over-moist and over-full diet ;
- (3) a delicate kind of life abandoned to ease and voluptuousness, slothful and rarely accustomed to labour, danger and care.

Speaking of the increase of rickets in the south-western counties of England, as compared with the rest of England, he specifically states, in a passage already noted, that the essential cause is the affluence of all good things in these counties, " for this part of the kingdom is much the more fruitful, rich and flourishing and abounding with all manner of allurements to pleasure."

The poor led a healthier, if rougher, existence, and in the homes of the labourer there was but little comfort to conduce to long hours spent luxuriously indoors. Labour was mostly employed in the fields, and the life of the whole family, parents and children alike, was spent much in the open. The influences spoken of by Glisson are the same which induce rickets to-day, but with the essential difference that these conditions, such as confinement in badly ventilated and overcrowded rooms, lack of exercise, lack of sunshine and lack of the opportunities of cleanliness, are to-day concentrated in the homes of the poor in our slum areas. It may again be reiterated that in a climate such as ours the conditions of the slum may be reproduced in the most beneficent surroundings. The occurrence of defective and impaired growth in the midst of beautiful country, abounding in rich dairy produce, is as striking to-day as in Glisson's time, although the deviation from the normal is not so wide. Even to-day, as has already been noted, in the south-western counties of England, evidence can be found of the disease in the home of the better-class farmer, as well as in the cottage of the farm labourer—a somewhat striking fact, for rickets is a disease which presents class distinctions and tends to bear chiefly on the lower grades of society. During our prolonged and inclement winters, damp and cheerless dwellings between the hills and ignorance of the first principles of healthy living can reproduce, even in such unlikely surroundings, the vicious environment of the slum. Wholesome food is necessary, and of all food none is so conducive to the well-being of the infant as the breast milk of a healthy mother. Equally essential is a bright and healthy environment with ample fresh air and opportunity for exercise. The environmental factor is the one which constantly fails in rickets, and is the sole agent without which the disease cannot be reproduced. The food factor is much less likely to fail, and if it does even to the extent of producing marasmus and acute wasting, it never in itself produces rickets.

The record for the study of rickets in the world's history

is a long one, for wherever there is a skull or a skeleton there is a document which can be scanned for evidence of the disease. In Neolithic remains and those of the Bronze Age, down through the Ancient British period to the Roman occupation of England, and from thence to the Anglo-Saxon period, and up to mediæval times, there is a striking and complete absence of the disease. This is the more noteworthy, for there is no lack of evidence of the existence of marked bone disease even in remote times. Osteo-arthritis of a severe type is especially common. The further one gets back to crude and remote periods, the greater is the evidence of a harsh and severe struggle for existence. The growth of the people is stunted and the incidence of the stress falls chiefly on the women, who are affected out of all proportion to the men.

It would seem as if these conditions must have borne most hardly on the offspring of such a people, but the few facts there are, such as those detailed in speaking of the remains of the Upper Nile (see p. 316), seem to show that the infant to a large extent escaped, and that the stress told on the adult, leading to stunted growth and an early invasion by disease and shortened expectation of life.

Taking the variability of such a factor as height in the present population, the tendency has been to regard it as almost entirely the result of heredity. This result has been arrived at by measuring the variations in the heights of the parents and comparing these with variations in the heights of the offspring, and also by measuring the amount of variation between brothers and sisters.

But caution must be observed in ascribing what occurs in the parent and child alike, even over large numbers, as necessarily being due to heredity. The evidence of history would seem to show that, apart from racial differences, where certain conditions such as defective feeding are universal over a large population, the result as regards growth in weight and stature will not be so good as if food were abundant and of good quality. Still more important, I believe, is the effect of environment. In new countries the

population derived from European stocks tends to increase in stature generally, a fact which was apparent in the colonial troops recruited in the late war, as compared with those recruited from the industrial centres of our great towns.

The important function of heredity is not to produce variation but to stabilise the type and produce a healthy average. But to do this to the best advantage nature demands favourable conditions, especially of feeding and environment.

The effect of placing the bulk of the community under conditions of town and slum dwellings introduces factors which, owing to the universality of their operation, are exceedingly difficult to distinguish from hereditary influences when brought to bear upon a whole community over prolonged periods.

In speaking of the skeletal remains of the ancient inhabitants of Egypt and of Coptic peoples, it was stated that the evidence seemed to show that the incidence of disease in the young infant and child mortality were probably much less than they are to-day. The conspicuous absence of the study of children's disease from the writings of the ancient classic writers has already been commented on. Hippocrates and Galen were no mean observers. In these early civilisations the probability is, that diseases of the adult, in the form of defective elimination, were more prominent than errors of growth in the young infant.

In the Royal College of Surgeons there is arranged in series a large number of skulls from Neolithic times up to the present day. Through the various periods the skulls show wide racial differences, but, whatever the period and no matter how varied the shape of the head up to a comparatively recent date, say, the close of the sixteenth century, the jaws and teeth, the best records of the rachitic state, show the same conformation. The vault of the palate is depressed and wide, and not high and vaulted as it tends to be in the modern skull. The alveolar borders are widespread and the teeth are nearly all present. There is but

little liability to decay, notwithstanding the roughest usage, and hypoplasia is conspicuously absent. The large collections of bones in English crypts up to and beyond Reformation times are remarkably free from rickets, while syphilis, tubercular disease and osteo-arthritis, are often well marked.

The modern type of skull does not, indeed, become common till the beginning of the eighteenth century, since when marked and rapid change has occurred in the skull corresponding with the growth of towns and the development of modern industrial centres.

I would class the modern English skull as dating from the beginning of the eighteenth century, and the variations which have occurred are, I believe, the result of altered environment acting continuously and widely over a great and increasing population. There are undoubtedly many other factors to be considered, such as the employment of women and children under deplorable conditions in factories, which had a great influence on the health of the community. The evil results of work in the factories, especially in the case of expectant mothers, must have had deleterious effects on the offspring, though it is possible to exaggerate these. The conditions of women's labour have, however, been very much ameliorated for several generations, but rickets remains as common a disease as ever, though the degree of severity is undoubtedly mitigated. Child labour had most pernicious results in thwarting and retarding the development of the young child, but these were not the conditions which produced rickets, for the disease arose as the result of evil environment, bearing on the young child from soon after birth up to the end of the second year.

What, then, is the nature of the environment which produces rickets? It is that associated with the overcrowding of immense populations into slum areas, accompanying the development of industrial conditions in large towns and cities. It implies several factors :—(1) absence of sunlight; (2) deprivation of fresh air, and of the means of proper oxygenation of the blood and removal of

carbonic acid, required for the metabolism of the healthy infant; (3) deprivation of the means of exercise which is so essential a stimulus to the proper regulation of the process of growth; (4) the breathing of an atmosphere polluted by overcrowding in confined and badly-ventilated rooms; (5) the want of the opportunity for proper cleanliness.

The transformation of the people of England from a sparse rural population to an enormous densely-packed industrial one has taken place within the short period of three hundred years. Nature has had to deal with a problem which menaced the very life and continuity of the race within the northern temperate zone.

Picture a child born in a small damp basement room in Hoxton or Shoreditch. There is a family of four or five, perhaps more, in one, two or three rooms. All the household operations, such as cooking and washing, have to be carried out in these living rooms. There is no bath. Ventilation is as restricted as possible during a large portion of the year. During the day there is no fresh air and at night the conditions are worse, for the child in slum populations almost invariably sleeps with the mother. The separate cot for the infant is a desirable reform which the infant welfare worker knows is one of the most difficult to carry out.

These are not occasional conditions, nor are they the environment of a century ago, but, as has been shown in the case of the north-east sector of London alone, which includes a population of a little over 900,000 people, are the ordinary conditions in which 314,000 of these people live to-day. Careful examination shows that overcrowding and confinement in small rooms are the essential factors wherever rickets is prevalent. Whether in England, or Europe, or America, the greatest prevalence of rickets is associated with the greatest density of population.

The metabolism of the young infant is exceedingly rapid, and growth takes place out of all proportion to the mere food intake. After the first few months the expenditure of energy in the form of actual exercise is very great. The child is seldom still; it loves to exercise its muscles in short

jerky movements. From an early period it carries on a continuous babble when awake, and cries lustily to indicate its needs. To carry on this active metabolism, and these expressions of its vitality, a rapid respiratory interchange must take place. To a large extent the young infant feeds upon air. That this is actually possible is seen in the hibernating animal, which not only lives upon air but may actually gain weight without any fresh intake of food whatever. It is a matter of everyday experience that a change to fresh air and fresh surroundings may be productive of the most striking difference in the health of the young child suffering from debility, producing an immediate increase in growth and vitality. Without any change in the diet, or even on a poorer diet, the beneficial effect produced by the mere change of air is often most striking.

It is generally recognised that the breathing of vitiated air tends to produce ill-health and renders the body more liable to infection and disease. I have been repeatedly struck with this while investigating rickets in the East End of London in some of the older London County Council schools which have been deficient in the means of ventilation.

In such a school, on entering a classroom, the observer is conscious of an offensive smell from the vitiated air of the room. The olfactory sense is extremely susceptible to variations in closed atmospheres, suggesting an important protective measure. The teachers and pupils alike show the evil effects of the breathing of polluted air. Anæmia is common; the children are pale and the skin has a muddy yellow tinge. Discharging ears are very frequent, much more so than in other schools better situated, indicating the presence of adenoids and naso-pharyngeal infections. Myopia is often exceedingly prevalent. The teachers have frequently informed me that it was practically impossible to retain the attention of the classes in the afternoon, and they complained that they themselves found it exceedingly difficult to concentrate on the work in hand. Head-aches and recurring catarrhal colds are very common. To

add to the distress, as is usual in badly constructed buildings, there is but little movement in the air and it is difficult to keep the rooms cool in summer or warm in winter. The air of overcrowded rooms may be vitiated in various ways, and several factors have to be considered.

1. *Increase of Carbon Dioxide.*—The mere fact that there is an increase of carbonic acid in the room does not mean that there is necessarily a corresponding increase in the tension of carbon dioxide in the lungs. Just as there is a heat-regulating mechanism which keeps the body temperature constant under varying conditions, so there is an adaptive mechanism whereby the amount of carbonic acid in the alveoli is kept fairly constant. The proportion of this gas is the usual index taken to indicate the impurity of air, but it is by no means a certain test, for air which, judged by the amount of carbon dioxide may seem fairly pure, may be very impure when judged by other standards such as the number of organisms present. Experimental results seem to show that large quantities of carbonic acid may be present in the air without untoward results. Thus one can breathe with moderate comfort in a room the air of which will not support a light. Increase of carbon dioxide tends to produce hyperpnœa and headache, both of which may be prevented by withdrawing this one content.

2. *Diminution of Oxygen.*—Experimentally this is well borne, and respiration can be maintained in atmospheres deprived of oxygen to an extent which is never found in ordinary vitiated atmospheres.

So far as the ratio of carbonic acid gas and oxygen in the atmosphere is concerned it would seem from experimental observation that there is room for a wide variation without harmful effect to the individual. Dr. J. S. Haldane suggests that the function of the epithelial lining of the alveoli is not merely that of a porous lining. Normally, he believes that oxygen reaches the blood by a simple process of diffusion through this membrane, but that when a special demand upon oxygen is made by the economy that the living cells of the epithelium actually secrete oxygen from the air and

hand it forward at enhanced pressure to the blood. This property is, he believes, developed in miners, and is also capable of being improved by physical training. Conversely, it is reasonable to suppose that in a disease such as rickets this epithelium may have the power of limiting the exchange of gases and so damping down the whole process of metabolism, which is so marked a feature of the rachitic state. Interference with the special functions of cells is, as has been shown, a common feature of rickets.

3. *The Presence of Organic Matter in Respired Air.*—Once again, experimental results are conflicting and inconclusive. Brown Séquard and d'Arsonval found that the injection of soluble organic matters exhaled from the lungs and skin into the circulation caused death, as also did the constant breathing of these products.

Haldane and Lorrain Smith repeated these experiments but were unable to confirm these findings.* They came to the conclusion that the immediate dangers from breathing a highly vitiated air arose entirely from excess of carbon dioxide and deficiency of oxygen and not from any special poison. Subsequent to these experiments, Dr. Sigmund Merkel† published results again confirming the work of Brown Séquard. Four air-tight glass vessels were connected by means of glass tubes, a mouse being placed in each vessel. Between the third and fourth vessels a Geissler absorption-tube containing sulphuric acid was interposed. Air was drawn slowly through the vessels by an aspirator so that the second mouse breathed the air from the first, the third from the second and the fourth from the third. The result was that the mouse in the third vessel died first, after sixteen to twenty hours, while that in the fourth vessel remained alive. Merkel concluded that, as the fourth mouse remained alive, the death of the third cannot have been due to an excess of carbonic acid, or to a deficiency of oxygen, but must have been caused by the presence of some volatile substance

* "The Physiological Effects of Air Vitiating by Respiration," by John Haldane and J. Lorrain Smith, *Journal of Pathology and Bacteriology*, 1893, Vol. I., pp. 168 and 318.

† *Archiv. für Hygiene*, 1892, Vol. XV., p. 1.

which is absorbed or destroyed by the sulphuric acid. Again, Haldane and Lorrain Smith were unable to confirm these results.

The air of overcrowded rooms contains an increase in the number of micro-organisms. Apart from the chemical composition, the physical properties of the air, such as temperature, humidity and movement, are all potent factors in the maintenance of health. A continuous warm, moist atmosphere is most depressing to all the functions of the body. This is usually combined, under conditions of overcrowding, with stagnation of the air. As a result the general metabolism of the body is diminished and the appetite is poor. The tone of the muscles is impaired, and there is a lack of nervous and muscular energy. Free stimulation of the skin by a moving and constantly varying atmosphere, such as is met with in the open, is most wholesome in its effect on the general metabolism. Even the adult when confined indoors soon shows the effect of the loss of such stimulation and tends to lack energy and to become sallow and pale. It can be readily understood that a warm, moist and motionless atmosphere such as the child of the slum dweller lives in for weeks and for months together must have a most depressing effect.

There can be no doubt that the breathing of impure air is very unwholesome. Experiments are unsatisfactory in that they do not reproduce the conditions under which such air usually acts. In experiments, an adult presumably in good health remains in a chamber for a few hours. The young infant, on the other hand, remains day after day and week after week in an atmosphere contaminated by young and old, while disease and dirt also add their impurities. Kassowitz, indeed, believed that the breathing of ammoniacal exhalations owing to insufficient cleanliness was a common cause of rickets. Whether or no there is an actual toxin in respired air, it is at present impossible to say, but clinical evidence certainly seems to support the experimentalists who find such products are present. That there are certain organic impurities in respired air seems certain from the

sense of smell, and also that they have a deleterious effect even though they may be minute in quantity. The long-continued action of such substances may induce through the central nervous system alterations in respiration, circulation and nutrition, which are inconsistent with the maintenance of good health. If the air is stagnant and still, the moisture-laden emanations from the body are imprisoned and entangled by the clothing, and a humid layer of foul air hinders further evaporation.*

Consider the position of a young infant exposed during the first few months of its life to the deleterious influence of such an atmosphere ; even in a modified degree, such as may occur in the " stuffy " room of the better-class house, the effects are most harmful. The rapid exchange of gases in the act of respiration is interfered with. There is a slight increased tension of carbon dioxide in the alveoli, and this gas is not efficiently removed from the blood. Hyperpnœa results and heavy sweats are induced owing to the effort of nature to relieve the system of the excess of carbonic acid. The supply of oxygen is interfered with, and the damp, moist, frequently overheated air acts as a further depressing agent. As already stated, whether or no there is a definite organic toxin in respired air is still in dispute, but there can be no doubt of the extremely unwholesome results of breathing such air, which in many well-known and extreme cases has ended in death. It is obvious that a robust child full of life and vitality could not long survive under such conditions and still retain its full vigour. Nature, according to John Hunter's axiom, meets the altered conditions by a process of conservation and holding up of the entire metabolism of the child. In the rickety infant the metabolic processes are at a low ebb. There is an absence of energetic movement. Respiration is hurried but it is shallow, and the quantity of air taken into the chest is the smallest amount that the organism finds essential for carrying on its work.

The enlarged and tender epiphyses at the ends of the

* Parkes and Kenwood, " Hygiene and Public Health," London, 1917.

softened long bones further restrict the child's desire for movement. The very great muscular debility is in conformity with the general plan of producing an organism capable of living in an environment where a healthy vigorous child could not long maintain its existence. Nature, ever mindful of the continuity of the race, is often heedless as to whether or no her process of natural selection is beneficial to the individual; if a feebler type is necessary for the perpetuation of the race owing to overcrowding in great towns and widespread unhygienic conditions, the type of individual fitted to live under these conditions will undoubtedly be produced. Such is the rachitic infant. Heredity even may step in, for it would seem to be the case that when conditions threaten the actual life of the germ, an adaptive change may readily occur in the germ plasm itself, and Glisson's idea, which accords with common experience, that weak, debilitated parents tend to produce a debilitated progeny may easily be true. But that does not imply that rickets is hereditary.

All these conclusions would appear to point to inimical influences acting through the air, whether it be the result of the overcrowding of the poor, or over-care and coddling of the rich in close stuffy rooms. The healthy child delights in free movement which entails vigorous action of the respiratory and circulatory functions to carry on the rapid oxidation and removal of effete products necessary for this abundant expenditure of energy and the processes of growth. In the rachitic child all these processes are "damped down" as it were. The child is silent and moves but little. The processes of growth are delayed and the formation of osteoid tissue and irregular calcification of the cartilage indicate that provision is being made for growth of the bone, but that the process of building up, which should take place, is being held up because of a failure in the economy of the child. Few things are more striking than the way nature again resumes her work immediately environmental conditions improve.

Why is it that a child suffers from rickets only during

the first two or three years of life ? The disease, of course, may occur at any time up till complete ossification takes place at the ends of the long bones and, as has been stated, true cases of late rickets occur at adolescence which may be either a recrudescence or a new outbreak of the disease. Such cases are, however, by no means common. Rickets is usually recognised clinically between the ages of six months and eighteen months, though in the routine examination of an infant welfare centre the physician will often be able to pick out cases even before the sixth month. The reason why the disease is confined to the first two years of the child's life is because the full force of the vicious environment is brought to bear on the child at this period. The infant is entirely dependent on the mother for exercise and fresh air. In the winter in England during the short days the busy mother of a family in a poor home has but little time to devote to taking her baby out in the open air. She is content if the child lies quiet while she carries on her household duties. At night the windows are closed for the sake of warmth and the child sleeps with the mother, so that all the evil conditions of the day are present in an exaggerated form at night. Even in a good class home it is exceedingly difficult during the inclement winter months for the mother or nurse to give the child sufficient outdoor exercise, and care must be taken to utilise every half hour of sunshine or fine weather that is available.

Why does a child begin to throw off the disease about the third or fourth year ? There has been no improvement in the diet. Indeed, as the child grows older, it is not, as a rule, so favoured as the young infant for whom the best and most wholesome part of the diet is usually reserved. Nevertheless, these children almost invariably improve at this age, and the common statement of the mother is, that all her children pass through the same delicate stage, but that they all get stronger by the age of seven, and long experience has taught her not to worry. There is a good deal of truth in what these mothers say. Immediately the rickety child struggles to its feet about the age of two or three years and

begins to lead a separate existence, and especially when it is allowed the relative freedom of the streets, it begins to improve rapidly. This delayed development of the rickety child both in physical and mental growth, and the comparatively rapid improvement which occurs from the age of five to seven years is well known to teachers in primary schools.

The Part played by Sunshine in the Prevention of Rickets.

—It is well known that rickets especially favours damp and cold climates where the skies are grey and sunless, and where a curtain of smoke hangs over great cities, screening away a large proportion of what little sunshine there is. No plants will grow in these areas, and special provision must be made if trees are to survive. That sunshine has a very direct action on the economy is certain. The feeling of elation and *bien-être* felt in bright weather is an indication of its effect on the adult metabolism, and it can readily be understood that it is likely to be an important factor in the healthy development of the child. The young infant can no more flourish than the tree or flower if it be entirely deprived of sunlight. It is well known that the rays at the violet end of the spectrum—the actinic rays—are chemically active. They hasten the hatching of frogs' eggs, for instance, and they kill many bacteria, including the tubercle bacillus. They produce heliotropism in plants. The rays in the middle portion of the spectrum are less active chemically, but they stimulate the growth of plants while the red rays have heating properties.*

It is difficult to say precisely in what manner sunlight plays its part in the prevention of rickets, but that that part is a large one is very certain. A study of the geographical distribution of the disease, even with our present imperfect knowledge, establishes the fact that where brilliant sunshine is constant, as in Egypt, India, China, South Africa, and New Zealand, rickets, for all practical purposes, does not exist. Now it is well known that in the teeming populations of the Far East overcrowding and insanitary conditions are apt to be very prevalent. The hut of the

* "Air and Health," by R. C. Macfie, London, 1909, p. 104.

native, judged from the European standpoint, lends but poor accommodation to its many occupants, but this is not the type of overcrowding which causes rickets. The young of animals in their burrows lie curled up with the mother under conditions which may be held to resemble the surroundings of the slum dweller, but the disease never develops. The reason is that the life of the wild animal and the life of the native are largely regulated by the sun. The native infant, as soon as the sun is up, is allowed to play outside the hut or habitation, and continues to be bathed in sunshine till the time of rest at sunset. Under such circumstances rickets does not develop. It is possible that with the development of European conditions in the East a slight tendency to the disease may develop, but it is likely to be of a modified type. In Australia, under conditions which are not conducive to rickets, slighter forms of the disease have appeared as the larger towns have grown in size and density.

Such theories as to the ætiology of rickets have long been known, and it is noteworthy that practically every writer who accepts the dietetic theory of the origin of the disease hastens to state that the breathing of vitiated air, lack of sunshine, and lack of exercise, are powerful contributory factors. Even those who support the view that it is a deficiency disease, that is, that it is due to the absence of an accessory food factor or vitamin, hold that defective hygienic conditions are contributory. Why this should be, if the vitamin theory be true, it is difficult to say. Other deficiency diseases are clearly due to the absence of a factor necessary for the maintenance of health, and occur whatever the surrounding conditions may be. Beri-beri has an enormously wide distribution over the East in all sorts of varying conditions, while scurvy and Barlow's disease may, and frequently do, occur in good homes, where all the conditions are entirely favourable except for the absence of the anti-scorbutic factor from the diet. Defective and deficient feeding of infants, and ignorance of the elementary principles of dietetics, are found all the world over. They are

more prevalent in the East than in the highly civilised and wealthy populations of Europe and America. Nevertheless, rickets as a disease is practically confined to the northern temperate zone between well defined limits, and under certain definite conditions only found in this zone.

In 1906 Von Hanseemann * published his well-known domestication theory of the origin of rickets, and, though the ætiology of the disease cannot so far, according to this theory, be pinned down to any one factor as the actual exciting cause, it fits in with all clinical experience. The vitamin theory is a tempting and facile explanation which is contradicted by the study of the geographical distribution and of the history of the disease, as well as by the clinical evidence.

It is interesting to note that in the enquiry by the National Health Insurance Medical Research Committee into the causes of high rates of infant mortality, Dr. Brend † comes to the following conclusions :—

- (1) that excess of infant mortality has very little relation to pre-natal conditions ;
- (2) that the excess is due to some factor or factors in industrial towns, the centres of large cities, and mining areas, of which possibly the most important is a polluted state of the atmosphere.

* "Uber die Rachitis als Volkskrankheit," Berlin, Klin. Woch., November 9th, 1906.

† "The Mortalities of Birth, Infancy and Childhood," Special Report Series, No. 10, published by His Majesty's Stationery Office, London, 1918.

CHAPTER XXVIII

The *Ætiology of Rickets* (*continued*)

Rickets and the Endocrine Glands.—The rachitic state is associated with the breathing of a vitiated air at a time when fresh air and the free interchange of carbon dioxide and oxygen are most essential to the young infant. There is an inhibition of all free movement and the child is deprived of the stimulating effect of daylight and of the sun's rays. Many diseases are associated with similar conditions. Typhus fever, though due to a micro-organism, is nevertheless a disease associated with overcrowding and insanitary conditions. Free ventilation in sunny wards contributes to its cure and effectually prevents its spread.

Cretinism is a disease with a distribution not unlike that of rickets, and is associated with sunless valleys and dwellings. Formerly many cases of sporadic cretinism were attributed to foetal rickets. In its early manifestations it exhibits many of the signs and symptoms of rickets in an exaggerated form.

Tuberculosis is notably associated with similar conditions, as also are various forms of anæmia and general impairment of health.

In the rachitic state, nature produces the lymphatic child with quick, shallow breathing, holding in strict reserve all its activities, so that no undue demands are made on the respiratory exchange and the breathing of vitiated air is made as limited as possible.

In the present state of our knowledge of the function of the endocrine glands it is undesirable to dogmatise as to the special part each plays in the economy of the body. Their secretions are so widely operative in growth and metabolism generally, and are so linked up with each other, that there is a danger of fitting their function to suit any theory which requires support.

At the same time certain broad facts seem quite definitely decided. That the thyroid gland and the pituitary body, for example, both stimulate growth is now well established. This is shown, in the one case, by the action of the thyroid gland in cretinism, and in the other, by the enlargement of the bones of the face and jaw, and of the hands and feet as the result of disease of the hypophysis cerebri.

Growth may be considered from two points of view, viz., firstly, foetal growth, in which is epitomised the whole evolution of the species, and secondly, the development of the somatic or physical characters of the individual. Both these modes of growth are largely the result of the combined action and interaction of the endocrine glands.

It is accepted that man is the highest evolved animal. He is also the most highly specialised of all the primates, but that is not equivalent to saying that he is the farthest removed from the parent stock. Indeed, the contrary is the case, for man has persisted, as it were, along a certain definite line, and retains many foetal characteristics which are lost in the anthropoid apes. In other words, the anthropoid ape is travelling along a line away from the original stock and is forsaking the human type.

For instance, the hand and especially the foot in man retain more of the foetal type than in the other primates. In the anthropoid ape the hand and still more notably the foot are modified so as to depart widely from the foetal type. This change is produced by the action of the glands of internal secretion, and probably the gland chiefly responsible for this special change is the pituitary. This is suggested by the fact that in acromegaly the hands and feet of man tend to assume ape-like characteristics, and to depart from the foetal type. Again, the small development of the bones of the face and of the jaws in man is a persistence of the foetal type, while the prognathous development is a pithecoïd departure from the foetal type due to the action of the pituitary gland. In acromegaly there is a marked tendency to the development of this characteristic in man.

Up to a point, man and the other primates have deve-

loped along certain lines together, and the extent and direction of the growth has been largely moulded and determined by the action of the endocrine glands. At various times, however, certain departures from the parent stem occur. In the anthropoid ape, for example, the action of the endocrine glands is so modified as to produce an evolution along lines which lead away from the human type, which remains simpler and more true to the foetal form of development. In diseased conditions involving the glands of internal secretion in man the type of growth is apt to assume an anthropoid character.

That is to say that in man, in the growth of the hands and feet and in the tendency to prognathism already instanced, there is normally a repression of the function of the pituitary gland, which repression may, however, be removed as the result of disease. Prof. Bolk, of Amsterdam, states that he knows of no new developmental somatic characters in man, unless it be in the muscles of the face and the intrinsic muscles of the larynx, and that all the other distinctive human characters are the result of the suppression of the action of the endocrine glands and the perpetuation of the foetal type.

It is well known that in apes the sutures of the skull close early, and that the development of the young is hurried forward so that maturity is rapidly reached.

In man, on the other hand, the closing of the cranial sutures is considerably delayed, and the foetal or child-like stage is greatly prolonged. In the anthropoid ape the secretion of the internal glands hurries forward these processes, but in man the action of the glands is retarded.

In the new-born infant there is an enormous internal impulse to growth. So great is the energy that a brake is required, and this is probably found in the thymus gland, which attains its maximum function in the first few years of life. The thymus is held to be intimately associated with the process of bone formation, though this has not been definitely proved and the evidence is still somewhat conflicting.

The thyroid apparatus is certainly concerned in the process

of ossification, the parathyroids especially having a controlling influence on the calcium metabolism. That these two glands, the thymus and the thyroid, are active during the early life of the infant is beyond doubt, and that they have a direct influence on the pathogenesis of rickets seems very probable. The thyroid is an accelerator of growth and is katabolic in its action, the thymus, on the other hand, is conservative in its action and is anabolic.

The thyroid system, then, consists of the thyroid gland and the parathyroids, and the morbid conditions associated with this system may be divided into hypothyroidism and hyperthyroidism.

Various diseases are commonly associated with these two morbid states, though no hard and fast line can be drawn between them. Thus, to the hypothyroid state belong such conditions as the benign hypothyroidism of Hertoghe, myx-œdema, cretinism, various spasmodic affections such as tetany and paralysis agitans, and rickets itself. To hyperthyroidism belong goitre and Graves' disease.

All clinical experience shows that for the proper functioning of the thyroid apparatus, especially in the young, a free life much in the open is essential. Deficient ventilation and the breathing of an unwholesome atmosphere, want of sunlight, and want of exercise, in other words an absence of all the healthy impulses to growth, are the essential factors producing the rachitic state, through the endocrine system.

The question naturally arises as to whether or no there is an actual toxæmia in rickets, and if so what is its nature and source. The presence of some organic impurity in the respired air suggests itself clinically as a probable factor, but it is unsupported by experimental evidence. But experimental results as regards questions of general hygiene and the function of respiration are notably inconclusive. It is practically impossible to reproduce in the laboratory the conditions which surround the young infant in the slums during our long and dreary winters. Much more trustworthy evidence is to be obtained by watching great natural experiments, such as the effect of the transplanting of southern and

native races into the midst of civilised communities within the temperate zone, whether in Europe or America ; or the converse may be watched in the transformation which occurs in the slum dweller when transferred to the freer life of the colonies. Reference has already been made to the great natural experiment among the Jews in the East End of London, where excellent conditions of feeding are associated with very defective conditions as regards environment and general hygiene.

Another possible source of toxæmia which suggests itself is bacterial infection, which will be dealt with more fully later. Infections of many kinds are common in rickets, especially those of a catarrhal nature affecting the mucous surfaces. It is a possibility, however, to be kept in mind that in rickets and in such conditions as endemic goitre the action of varied organisms may be part of nature's process of adaptation and not the assault of a pathogenic germ such as occurs when the body is invaded by the bacillus of typhoid fever or the pneumococcus. It is certain that this aspect of the production of diseased conditions has not received the attention it deserves, notwithstanding that the theory of artificial immunisation is based on such an assumption.

The thymus and the lymphatic structures generally, being essentially conservative structures, are unduly developed wherever control or slowing of metabolism is required. Lymphatism tends to lead to an increased deposit of fat such as is seen in fat rickets. It is markedly associated with hibernation where a holding up of all the vital processes is very essential. Contrary to what was generally supposed, Hammar, of Upsall, showed that the thymus increased in size up to the age of puberty, diminishing between the ages of fifteen to twenty-five years till at the latter age it corresponded with the size at birth. At birth the thymus weighs five grams, at puberty twenty-five grams, and from fifteen to twenty-five years it shrinks in size till at twenty-five years it again weighs five grams.* In rickets depraved action of the thymus, thyroid, and parathyroid glands leads to still

* " Internal Secretions and Principles of Medicine," by Charles E. de M. Sajons, 8th Edition, Vol. I., Philadelphia, 1918, p. 280.

further delay in the closing of the cranial sutures and to an undue lengthening of the foetal or child-like stage. Not only are the bony sutures of the cranial vault late in closing but the eruption of the teeth is notably delayed, and the faculty of speech and the general mental development are also retarded. Two facts, then, seem to stand out clearly—that there is an overgrowth of the whole lymphatic system, including the thymus, in rickets, while at the same time there is defective action of the thyroid apparatus. Now the thyroid opposes the thymus, in that it is the great accelerator of metabolism, and is probably the great controlling influence presiding over all the other glands of the endocrine system. All observers from the time of Glisson onwards are agreed that clinically the thymus and the general lymphatic system are enlarged in rickets.

The question of a possible antagonism between rickets and tubercle has already been referred to. The absence of pulmonary tubercle from infants and young children is very striking. It is very rare to find evidence of tuberculosis of the lungs in school children even when the conditions as regards general nutrition and environment are at their worst. In adults in these same areas the incidence of tubercle is very great and the death rate is high. *A priori* one would expect it to be very prevalent in the young infant. Evidence of invasion by the tubercle bacillus is not so uncommon in rickets as was formerly supposed. It has already been shown that tubercle in the child chiefly affects the lymphatic glands, the growing ends of the long bones, and the joints, the very sites where active changes are proceeding in rickets. If the defence of the lymphatic glands break down, a general form of acute miliary tubercle not infrequently supervenes, rapidly carrying off the child. Moderate degrees of enlargement of the mesenteric glands are not uncommonly found accidentally in later life where the tubercle bacillus has attacked the gland, but has not been able to spread beyond it, and it is very probable that the lymphatic hyperplasia of rickets materially contributes to this defensive mechanism. It is another instance of the adaptive power of nature, for

exposed as these children are, in an intensive form as it were, to the conditions producing tuberculosis, unless some effectual barrier were raised to protect the body from general invasion the disease would menace the continuity of the race in those localities where rickets prevailed. The development of the lymphatic state is one of the methods which nature employs to cope with the danger. The enlarged and hypertrophied lymphatic glands form an effective organic filter protecting the body from the invasion of the tubercle bacillus.

The action of the thyroid, the great accelerator gland of the body, is markedly depressed. Hertoghe pointed out that in the minor degrees of defective action of the thyroid—the state of hypothyroidism—there is a very characteristic train of symptoms. He showed that the thyroid governed the building up of the cells and regulated the destruction of the protein molecule; impaired action led to defective growth in the young child, and to the accumulation of imperfectly katabolised material in the adult. To this state of thyroid insufficiency he attributed such signs as relaxation of the articular ligaments, especially those of the knee, ankle and vertebræ. Eneuresis, a common sign in rickets, he attributed to the same cause.

The thyroid has important functions at most of the critical periods of life and is exceedingly susceptible to environmental conditions. Amenorrhœa is a common sign of hypothyroidism. It is a matter of concern to mothers and teachers alike that long periods of amenorrhœa are exceedingly apt to occur when girls are sent to boarding school. The food may be excellent, and the general hygiene of the school may be beyond reproach; the condition is not at all amenable to tonics, and as a rule after a varying period passes off spontaneously. The cause of the trouble is the over-careful regulation of the schoolgirl's routine. Her life of complete freedom at home is limited to one of carefully regulated exercise in the form of walks and modified games. The young growing organism demands less restraint and a wide range of freedom as regards outdoor exercise. There is much to be said for the modern development of free exercise

in the open, and the engaging in games which were formerly deemed unsuited to developing womanhood.

When a vicious environment produces its evil influence on the thyroid in the first years of life it can readily be understood that its effects will be even more serious. The parody of growth which occurs when the action of the thyroid is suppressed, producing cretinism in the young infant, is well known. When the efficiency of the gland is interfered with in cold, damp, and sunless localities, and in overcrowded slum areas, the effects, though modified, are far-reaching and are responsible for many of the characteristic signs of rickets.

There is, then, recognisable in rickets a certain type of child, which may be fat and well nourished, though the muscular tone and development are defective, often markedly so. The conditions associated with the rachitic state are strongly suggestive of hypothyroidism.* These may be detailed as follows: (1) coarseness of features and pale pasty complexion; (2) tendency to adenoids and catarrhal conditions associated with general lymphatic enlargement; (3) nocturnal incontinence peculiarly amenable to treatment by thyroid extract; (4) tendency to laryngismus stridulus and general convulsions so often associated with defective calcium metabolism; (5) pronounced harshness of the skin; (6) coarse scanty hair, without lustre; (7) backwardness of speech and slow general mental development; (8) softness and enlargement of the long bones at their epiphysial ends and thickening of the membranous bone of the shaft of the long bones, and of the flat bones of the skull; (9) hypoplasia and other defects of the enamel, with marked tendency to caries.

The degree to which these cases respond to thyroid treatment cannot be accepted as a true index of the extent of the thyroid deficiency. Personally, I have had some success with the treatment of cases of backward physical development and sluggish mentality, and also in the treatment of some special symptoms such as nocturnal enuresis; but in

* "On Some Signs and Symptoms of Hypothyroidism in School Children," by J. Lawson Dick, *Lancet*, September 5th, 1914.

my experience adenoid vegetations and enlargement of the tonsils have been but little, if at all, affected by the administration of thyroid extract. The ductless glands act very directly the one upon the other, and it is the sum of their combined energies which determines the line of growth.

When the whole process of growth is perverted owing to the want of harmony in the action of the various glands which are normally responsible for this process, and when this lack of harmony is due to a profoundly altered environment, it seems idle to expect much help from so crude a therapeutic measure as the administration of a gland extract.

The co-existence of myxœdema and rickets is not very uncommon, and Marfan has witnessed it on several occasions.*

In 1900, Stoeltzner † advanced the view that rickets was due to a defect in the supra-renal glands, but this has not been confirmed and has found but few adherents.

Lately it has been suggested that the absence of a vitamin or accessory food factor from the diet is the agent which produces the variation in the action of the endocrine glands in rickets. It has been shown that there is nothing to support, and much evidence to contradict, such a theory of the production of the rachitic state.

The Infective Theory of Rickets.—The resemblance of rickets to other diseases of bacterial origin has naturally given rise to the theory that a specific micro-organism may be the actual agent producing this disease. The very notable resemblance to syphilis would seem to lend support to such a view.

The theory that rickets is not a true or distinct entity in itself, but may be an end result of many different kinds of infection has already been commented on, in speaking of the history of the disease. Antoine Portal, in 1797, first elaborated this theory and spoke of venereal, scrofulous,

* Marfan, *loc. cit.*, p. 446.

† "Ueber Behandlung der Rachitis mit Nebennierensubstanz," von Dr. Wilhelm Stoeltzner, *Jahrbuch für Kinderheilkunde*, Vol. I., pp. 73 and 199.

scorbutic and other varieties of rickets. Parrot followed with a modification of this view, namely, that rickets was always the sequel of a syphilitic infection. These theories have been in the main discarded, though even so distinguished an observer as Prof. Marfan, of Paris, still holds a modified form of this view. Thus he maintains that syphilis, tuberculosis, prolonged broncho-pneumonia, staphylococcal infections of the skin and diverse other infections and chronic intoxications may end in the production of rickets.

It is impossible to accept such a view. Rickets, as described by Glisson, is a true and separate entity dependent on a certain pernicious environment without which the disease cannot be produced. True it frequently accompanies congenital syphilis and may be modified by it, but it remains a distinct disease with a different pathology and an entirely different outlook as regards prognosis.

Many experiments have been made with the object of establishing the bacterial origin of rickets. Morpurgo* claimed to have produced rachitic lesions in young rats by means of the artificial infection of the animal with a gram-positive diplococcus. Pappenheimer† brought about similar lesions in rats by the injection of a suspension of bone marrow from a rachitic animal. It must be remembered that the mere finding of bacteria in rickets does not constitute proof that these cause the disease. It has repeatedly been shown that to a marked extent rickets depresses the resistance of the body and predisposes very notably to the invasion of the organism by bacteria.

Endemic goitre is an interesting condition which has many points in common with rickets. Geographically, it has a rough resemblance to rickets in its distribution, being most prevalent in the temperate zone, though it is also found in regions of great cold and great heat. It is associated with clefts and valleys in mountainous districts, and is also preva-

* Morpurgo, B., "Ueber eine infectiose Form der Knochenbrüchigkeit bei weissen Ratten," *Verhandl. d. deutsch. patholog. Gesellsch.*, 1900, III., 40.

† Pappenheimer, A., "Further Experiments upon the Extirpation of the Thymus in Rats," *Jour. Exper. Med.*, 1914, XX., 477.

lent in the damp plains of Lombardy, Piedmont, and Alsace ; the courses of rivers and canals and marshy tracts seem to favour its appearance. It is markedly connected with defective air space, want of sunlight and bad hygienic conditions. All races of men suffer, and it seems to affect newcomers to an endemic area with unusual severity. The type of individual produced is the lymphatic type. Endemic goitre is very widely spread among animals whose habits have been modified by the vicinity of man, such as mules, oxen, horses, dogs, cats, goats, pigs, sheep, white rats, white mice, and in fowls and pigeons.

In two important points endemic goitre differs from rickets. It shows a seasonal variation, but unlike the rachitic process it tends to appear in March, April, May and June in the form of *summer goitre*.

It also differs from rickets in being more common in rural districts than in towns.

McCarrison * believes that endemic goitre is due to the presence in the alimentary tract of certain undetermined anærobic bacteria whose toxic products reach the bloodstream and induce in the thyroid gland hypertrophic, hyperplastic and degenerative changes.

Endemic goitre resembles rickets in that it suggests an attempt on the part of nature to adapt the individual to inimical surroundings. Both conditions are apt to be associated with the presence of micro-organisms, and it is possible that, even in rickets, the signs and symptoms of the disease may be found to be in part produced by the action of toxins of bacterial origin. Of this, however, there is no certain evidence up to the present time.

But, as already shown, that would not necessarily alter the fact that the essential cause of rickets was to be found in unhygienic conditions surrounding the young infant at a time when it is most dependent on a healthy environment. Indeed, it would rather suggest, as already noted, that the economy made use of the action of friendly bacteria in pro-

* "Endemic Goitre," by Robert McCarrison, *Practitioner*, Vol. XCIV., 1915.

ducing the modifications necessary to adapt itself to vicious surroundings.

It has been shown that the meconium of infants who have not breathed is entirely free from bacteria, but that micro-organisms appear within a few hours after birth. On a pure milk diet two species predominate, viz., the bacillus coli and the bacterium lactis, and appear to act as pure saprophytes, and to be related to the intestinal contents only. Under certain conditions it can be readily understood that many organisms may be called into action to help to adapt the child to the many and varied vicissitudes of environment to which it is exposed.

The bacterial origin of rickets has not been established, and while its possibility cannot be denied, the probability is that, if micro-organisms are found associated with rickets, their action is of a secondary nature and forms part of an adaptive process.

Heredity as a Factor in the Ætiology of Rickets.—The question of foetal rickets is a subject which has been hotly discussed for many years and which is far from settled at the present time. Glisson maintained that rickets was not an hereditary condition, though he believed that certain conditions in the parents predisposed to its production. In the transmission of disease from parent to child there may be an alteration in three factors :—

- (1) a child may inherit the anatomical and physiological constitution of either parent, and with that a special liability of failure to resist the attacks of a widespread disease. An excellent example of this is found in the tubercular diathesis. Since the discovery of the tubercle bacillus this condition has been but little noted, but the brilliant description by Sir Wm. Jenner of the tubercular diathesis which has already been referred to, remains as true to-day as it was in 1859 when Jenner described it :
- (2) the actual bacteria may be contained in the ovum or the spermatozoon :

- (3) the toxins of the disease only may have affected the ovum or the spermatozoon or, through the placenta, the growing embryo.

It is generally held that acquired characteristics cannot be inherited, but this is only partially true, and in a wider sense it might be argued that all inheritance is the result of the reaction of environment on the living and adaptive organism. It is largely a question of time ; for if a stress or strain is continued long enough it will in the end inevitably produce its effect. It has already been pointed out that a rite like circumcision, even when continued for centuries, has no appreciable effect on the phylogeny of the race, and therefore shows no tendency to produce an inherited character within any period of time which we can appreciate. When, however, circumstances arise like the sudden call to adapt a nation consisting of a rural population living in small communities widely distributed, to conditions such as appertain to-day, when a huge population is concentrated under the highly artificial conditions prevailing in industrial communities, a serious problem arises which affects the very continuance of the race so placed. Again John Hunter's theory may be quoted, that disease is but the normal response of an organism to an environment which demands alteration of development or modification of function or structure to meet conditions to which the healthy organism cannot normally respond. In other words, the production of the rachitic state is one of the means adopted by nature to meet such a contingency, for in this way an organism is produced better adapted for living in a vicious environment than is a more healthy and robust individual. But such an adaptation does not demand that the condition itself should be inherited, for the only need is that the child should respond to the environment when it is actually exposed to it, when it first leads an independent existence. The great probability is that rickets is never inherited, but is always an acquired condition.

Glisson, however, while he held that rickets was not a

congenital disease, maintained that certain ante-natal conditions tended to favour the occurrence of the disease in the offspring.

These, he believed, were mainly the conditions of life found in his day among the wealthiest classes of the community, such as indolence and ease and over-indulgence in the parents, tending to produce a weakly offspring, less resistant to such a disease as rickets than a healthy child would be.

The character of rickets has changed since Glisson's time, and the disease, though probably more widely spread to-day than it was then, is not of so severe a type and tends much more to present class distinctions, and to be a disease of the poor and of the slum-dweller.

Rickets in Glisson's day was comparatively a new disease, and it is a common experience in the history of medicine that when a population is exposed to altered conditions to which they have never before been subjected, or to a new infection, the disease which results is likely to be exceedingly severe. This may partly explain the extreme severity of the disease among the negro population in America to-day. It has been formerly stated that if the child of the slum-dweller were compared at birth with the child of the well-to-do, there probably would be no appreciable difference found. But that does not alter the fact that if ten thousand infants born in slum areas in our large towns, were compared with a like number from a country district there would probably be a balance in favour of the country children, not so large perhaps as might be expected, but still quite definite. In this sense there is probably a slight inherited predisposition to rickets in the offspring of rachitic parents, and the child is less resistant to the disease, but the actual condition never develops before birth. In other words, evolution, as formerly stated, does not necessarily mean an individual of a higher type, either physically or mentally, but may mean an individual better suited to his environment.

The subject of foetal bone disease has been much discussed of late years, and many cases have been carefully

examined and recorded, but no scientific classification on a pathological basis is yet possible. Formerly all cases of foetal bone disease were classed as rachitic in origin. In a general way there is a superficial resemblance in these cases, even when the pathological conditions vary considerably. Thus, in most the trunk of the body is normal, while the extremities are short and deformed, the head large and the bridge of the nose depressed.

There is a large group of heterogeneous bone diseases which has in the past been greatly confused, and is even now but little understood. Such are conditions due to scurvy and congenital syphilis, osteogenesis imperfecta, osteomalacia, achondroplasia, and the various forms of bone disease classed under the heading chondrodystrophia foetalis. Osteogenesis imperfecta is a disease in which the primary lesion is in the foetus while the mother is healthy; osteomalacia, on the other hand, affects the mother, who, as a rule, gives birth to a healthy child. Like rickets osteomalacia is a disease which suggests a failure of the endocrine glands. Scurvy is now generally accepted as due to the absence of an accessory food factor. Hess* strikes a note of warning which is very necessary at the present time, when he points out that there is a danger of grouping together unexplained and little understood diseases and attributing them to the overworked "vitamin" theory and classifying them as deficiency diseases; just as in the past there has been a danger of making the endocrine glands the dumping ground of any unidentified disorder.

Bone may reach its final form by two different routes—firstly, by development in membrane in which spicules of bone simply form in a membrane, as in the case of the flat bones of the vault of the cranium; or, secondly, by development in cartilage in which the scaffolding of the future bone is set up in cartilage which is removed later as the true osseous tissue grows up.

Ballantyne points out that the interposition of a cartila-

* "Scurvy, Past and Present," by Alfred F. Hess, Philadelphia and London, 1920.

ginous stage increases the possibility of formative failure.* Thus bone formation in the cartilage at the end of the long bones may come to a standstill while the membranous bone continues to be formed in the shaft and achondroplasia is the result. The development of the bone suggests one line of classification for foetal bone diseases, into those which affect the membrane bones only, and those which affect the bones developed in cartilage. Most of these diseases occur between the third and sixth month of intra-uterine life. Achondroplasia or chondrodystrophy affects the endochondral ossification only, never the intra-membranous bone. The flat bones and the vertebræ therefore escape while the bones of the extremities suffer most. The characteristic change in the skull is the early ossification of the tribasilar bone formed by two parts of the sphenoid and the sphenoidal process of the occipital bone. These cases not infrequently survive to adult life, and are quite commonly seen in London streets.

Chondrodystrophy or achondroplasia presents pathological appearances quite different from those which are present in rickets. These differences may be tabulated thus :—

CHONDRODYSTROPHY

(*Achondroplasia*).

Proliferating zone in epiphyseal line is narrower than normal, and is ossified at an earlier date.

Vascularisation not marked.

Bones laid down in cartilage are alone affected.

Basilar synostosis occurs early.

RICKETS.

Proliferating zone is much wider than normal.

Vascularisation very marked.

Membranous and cartilaginous bones are both affected.

Basilar synostosis does not occur early.

In achondroplasia there seems to be a simple arrest of development, while in rickets, though there is a delay of development there is also evidence of inflammation and a sluggish reaction to an irritant.

* "Congenital Rickets," J. W. Ballantyne, *British Medical Journal*, September 27th, 1902, p. 950.

Osteogenesis imperfecta (periosteal dysplasia) is an example of a foetal disease affecting the membranous bones. As its name implies nothing is known of its pathogenesis. The condition has a rough resemblance to rickets in that the bones are soft and gnarled and are very liable to fractures. The vault of the skull may consist of a multitude of small plates of bone. These cases have no connection whatever with rickets, and indeed, as these diseases of foetal life are becoming better recognised, cases of foetal rickets are being reduced to vanishing point. Glisson held that rickets was never inherited. Virchow believed that, if it occurred at all, it must be very rare. Sir Wm. Jenner and Cheadle had never seen a case of rickets at birth.* Stoeltzner, † of Berlin, and Comby, ‡ of Paris, do not believe in its occurrence.

On the other hand, Kassowitz maintains that rickets is exceedingly common in new-born infants, and Marfan also believes in its occurrence. Cranio-tabes is a condition which both these observers believe to be rachitic in origin, and as this is an exceedingly common disease of the foetus and of the first six months of extra-uterine life it is necessary, in order to maintain this theory, to believe that rickets is frequently of intra-uterine origin. As has been shown, however, cranio-tabes may occur as the result of many morbid states. It may arise as a result of rickets or syphilis, but it is pathognomonic of neither of these diseases. In many cases it seems to be a simple delay of development of the bone within normal limits which rapidly corrects itself. Its early occurrence before the sixth month would seem to support the view that syphilis is a commoner cause than rickets, for it is at this period that syphilis is especially operative. After the sixth month cranio-tabes almost invariably ends in spontaneous recovery, while the bony changes in rickets are only becoming evident.

The absence of hypoplasia from the milk teeth when first erupted is strong presumptive evidence that rickets is not

* Cheadle, *British Medical Journal*, November 24th, 1888.

† Stoeltzner, *British Medical Journal*, September 27th, 1902.

‡ Comby, *ibid.*

a condition which affects the fœtus. Defect in the laying down of the enamel is exceedingly common in the second dentition, dating as a rule from the first few weeks after birth. Calcification of the enamel of the milk teeth begins, as has been shown, about the middle of intra-uterine life. By birth a considerable portion of the enamel of the crowns of all the milk teeth is already calcified. If rickets were a congenital defect, handed down by parents, themselves affected with the disease, one would expect, with a condition so exceedingly common, that the immunity conferred by the mother would occasionally break down and hypoplasia of the milk teeth would fairly commonly be met with.

I have looked for several years for hypoplasia of the incisor teeth when first erupted in a large number of infants, and I have never met with a case. After birth the milk teeth suffer severely from defective laying down of the enamel and this is one of the chief causes of the widespread and early decay of these teeth. It may be objected that in the syphilitic child the milk teeth are also as a rule free from defect, though it is known that the infant is infected at an early period of intra-uterine life. But it must be remembered that the notching of the central incisors of the second dentition in Hutchinson's teeth is by no means common, and is not so widespread a condition as rachitic hypoplasia.

Even in syphilis, however, it is interesting to note that the protection afforded by the mother is very perfect, and in this disease also the enamel affected is that laid down almost immediately after birth. The occurrence of hypoplasia suggests some interesting problems in relation to the protective influence conferred by the mother during intra-uterine life and also during the period of suckling.

In the child with a well-marked tubercular diathesis the teeth are often very perfect and neither the first nor the second dentition tend to be affected.

It must be confessed that we are not yet in a position to state definitely what is the exact cause of rickets, though the field of enquiry can, I believe, almost certainly be narrowed down to the conditions of vicious environment

which prevail at their worst in slum areas. These are confinement and the breathing of a vitiated atmosphere in overcrowded and badly ventilated rooms, lack of sunlight and loss of the opportunities for proper exercise.

The child in the deep solitude of the womb is independent of these factors, but from its first entry into the world, its urgent cry is for a wholesome and pure atmosphere, to enable it to carry on its independent existence. True, these influences bear on the mother during pregnancy, but the adult organism does not react in the same way to these evil conditions as the organism of the new-born infant does. Again, the mother has a free and independent movement so that their effect is considerably modified, and during intra-uterine life the child lives under the protective influence of the placenta.

Life under modern highly artificial conditions in a cold and bleak climate such as ours endangers the normal progress of the child in every direction. When these conditions are very defective, as they are in the houses of a large proportion of the population of all our large towns, a compromise between complete efficiency and adaptation to environment must be come to. Modification of growth and development, largely under the control of the endocrine glands, takes place which, while it tells hardly on the individual, yet adapts it the better to maintain its existence under conditions which render vigorous and healthy growth impossible. These are the conditions invariably present where rickets is prevalent.

CHAPTER XXIX

The Treatment of Rickets

IN speaking of the treatment of rickets, there is not only a pathology of the individual to be considered, but there is a national pathology which must be treated on the broadest lines.

Rickets is a national disease which adapts the population to the demands of its environment. The welfare of the race is safeguarded in that the largest numbers possible are fitted to survive under conditions of modern civilisation which are far removed from the natural state, and the well-being of the individual is sacrificed to the needs of the many.

The enquiry into the ætiology of rickets is more than one of academic interest. Especially is this the case in the present economic state of Europe. No one doubts that it is highly desirable to improve the general environment, and especially to produce some amelioration of the housing conditions of the great mass of our population. But if rickets were of the nature of a true deficiency disease, and were due to the absence of a specific vitamin, as has been claimed, it would be wise to concentrate on supplying that deficiency, even at the risk of prolonging much discomfort, and limiting for a further period of years the amenities of life for a great mass of the population. It would be expedient to temporise with such large questions as housing and to concentrate on the more pressing need of adequate and proper feeding. Mankind is ever on the outlook for a short cut to health, and already the vitamin theory has seized on the imagination of the general public so that food values are discussed in terms of vitamin content instead of due consideration being given to a properly balanced diet derived from varied sources and capable of ready digestion and assimilation.

Diet is naturally of importance in rickets as it is in any other failure of metabolism from whatever cause, especially at the active period of growth. But no dietary, as has before been stated, will abolish rickets while the environment which actually produces the disease is allowed to continue, nor, on the other hand, will any defect or deficiency in the diet produce the disease, if the child is brought up under conditions where it is exposed to fresh air, and sunlight, and is allowed the free use of its limbs.

Of paramount importance in this pernicious environment is defective housing. It is only some eighty years ago that the question of housing and sanitation was first raised. Since then much has been accomplished so far as sanitation is concerned. The supply of wholesome and pure water, the regulation and inspection of food supplies, the proper disposal of sewage, and the isolation of smallpox and typhus fever, have achieved wonders. The main success has been attained in abolishing infective diseases dependent on filth conditions such as cholera, typhoid fever, typhus, and smallpox. Against other forms of infectious disease the campaign has not so far been successful. In 1917 there were in England 749,604 notifications of infectious disease, including measles 533,833, with a death rate of 10,538, and scarlet fever and diphtheria 92,132, with a death rate of 5,242. One important reason for the failure to cope with this efficiently lies in the ever-increasing growth of towns.

As regards housing, the probability is that the country is in a worse position to-day than at any period in our history. Fortunately, ideas of healthy living are becoming more and more diffused throughout the population, and the diminishing infant mortality must be largely placed to the credit of an intelligent motherhood rather than to any great improvement in public health administration.

Too much has been made of the incapacity of the mothers of the nation. Their ignorance as regards questions of ventilation and open air was shared by legislators who thought a window-tax a statesmanlike method of raising revenue. The problem of defective housing and overcrowding has been

beyond her power to deal with, and it has been beyond the power of the State to suggest any practical method of producing amelioration. Spasmodic and isolated efforts have been made with but little result. The growth of the evil is more rapid than the success achieved. Huge suburbs are growing up, it is true, but these rapidly reproduce the evils of the towns so that what was once fair country becomes squalid and ruined.

The ideal way to deal with slum areas would be to condemn and destroy all the houses within these areas, and at the same time to carry out extensive schemes of town planning for the population so displaced. It is obvious that in Europe where towns are the slow growth of centuries this is impossible. Happily, many parts of the world are still in the fortunate position of being able to carry out town planning on an extensive scale. In our colonies and in America, where it is not a question of abolishing slums but of creating new townships, a statesmanlike view is required to provide not only for the needs of to-day, but for the probable requirements of fifty or one hundred years hence. In England, towns have grown according to the need of the moment without any supervision or control. Houses and streets have followed rivers and railroads and have congregated round congested centres. Means of transit and ease of access have been more important considerations than matters of health.

A moderate estimate shows that to-day one-fourth of the dwellings of this country have less than four rooms, and that one-tenth part of the population lives under overcrowded conditions. Houses are arranged in rows of dreary streets which are often narrow and tortuous. Not only is the population crowded into these mean houses, but the houses themselves are packed close together so that there may be thirty, forty or even fifty houses to the acre. It is evident that the sweeping away of the accommodation of a tenth part of the population at the present time is impracticable, if for no other reason than the fact that there is no other housing accommodation available for them. This difficulty has been

much accentuated since the war, but constitutes no new problem. There has always been a shortage of houses suitable for the working classes.

Under such circumstances, care must be taken not to decry palliative measures because they offer no cure, nor on the other hand must we rest content with these measures because they produce a degree of temporary relief. Fairly extensive powers have been granted to local authorities who have not made sufficient use of them in the past. Thus they have the right to order that houses shall be put in a reasonable state of repair and made habitable, or if this is impossible, to order their demolition. Even at considerable expense, the most objectionable of these overcrowded tenements should be closed and destroyed by municipal authorities. In 1916 the Medical Officer of Health for Liverpool reports that the housing committee of the Corporation of Liverpool erected nearly three thousand dwellings on sites formerly occupied by insanitary property. The immediate results on the mortality were as follows :—

		General death rate per 1,000 of population.	Infantile death rate per 1,000 births.
1. Prior to demolition	...	40	300
2. After demolition in houses on same site		28	167

Such is not an isolated experience but is a common result in all town improvements. At one sweep the Peabody Fund in London has profoundly altered the health conditions of the people, so that of the 22,000 persons housed under this scheme, with weekly average earnings for the head of the family of only 22s. 3d., the death rate is only 10·4 as compared with 14·3 for the whole city of London. The London County Council has also carried out housing schemes which have shown excellent results. Not that such schemes are altogether healthy in their action, and may even be anti-social, in so far as they tend to crowd the population into the centres of the towns. These schemes, indeed, involve the writing off by the public body of the difference between the commercial value and the value for working-class dwellings of the site,

so that the houses are offered at terms which involve the payment of a heavy subsidy from the ratepayers to their tenants. No such subsidy is offered for houses in outlying districts, which is the true solution.

There is a natural tendency in London for factories to take the place of slum dwellings. In one or two cases it has happened that the London County Council has actually built schools in crowded areas where this has taken place, and has had difficulty subsequently in filling these schools. This displacement of slum houses by factories has been quite noticeable of late years in such areas as Shoreditch, Stepney, Islington, and elsewhere, and is a process which might well be encouraged by lowering the heavy rates which often drive manufacturers to look further afield for sites where these are not so oppressive. True, this is not an ideal method, but is only a palliative measure. The proper method would be to transfer both the factory and the factory worker's home into more congenial and wholesome surroundings in the country. But as a temporary measure it has its uses, especially in so far as it clears away noisome slums and replaces them by well-built factories without imposing any fresh burden on the ratepayer.

But while every method of diminishing the evil of slum dwellings should be adopted, the larger remedies should be consistently pursued. Continuity of effort is required rather than the occasional and spasmodic action which has been the rule in the past.

The development of the garden city has now passed beyond the experimental stage, and should be encouraged in every possible direction. This may be done in three ways. In the first place, ample powers should be given for the acquisition of land, compulsorily if necessary, at a reasonable rate. Secondly, improved and cheap travelling facilities should be established so that the workman can get to and from his work easily and quickly and in comfort. Thirdly, a well-planned scheme should be laid down which will not only deal with the construction of the house and the number of rooms, but will see that the streets are broad and well laid

out, allowing of free currents of air and the maximum amount of sunshine.

The number of houses to the acre should be strictly limited to ten, twelve, fourteen or eighteen, or some such reasonable number. The reserving of suitable sites for parks is a matter of great importance, especially to mothers and children. Often a common garden to several houses will form a large and useful space in place of small backyards which have no beauty and are of but small utility.

The development of infant welfare centres is a preventive measure of the greatest value. In these centres the child is seen soon after birth. The mother is encouraged to make regular visits at stated intervals. A record is kept of the weight and of the general progress, and the mother is urged to take the child each day into the open and to make the best of unpromising surroundings. Advice is given as to the feeding during the first few months and later at the difficult time of weaning. The constant supervision is of the greatest benefit to the infant and in almost every case the mother is anxious to co-operate with the physician in carrying out general hygienic principles.

Certain very essential matters it is often very difficult to achieve. The adequate ventilation of the rooms during the inclement weather of a long winter is often a matter of impossibility in the cold, cheerless rooms of the poor. Separate sleeping accommodation for the infant is a counsel of perfection which is seldom observed. There is the very practical difficulty that in the chill atmosphere of the room the warmth of the mother is often needed to maintain the body heat of the child. The result is that the breathing of an atmosphere vitiated by overcrowding in small rooms is accentuated during the night. Much, however, can be accomplished by the unwearying attention to small details. The mother should be urged to use any space or yard, no matter how small, provided it is in the open air, for the child to sleep in during the day. If the infant is kept warm and dry and is well clothed and well fed there are very few days in the year in which it cannot spend a considerable

portion of the time out of doors. The importance of through ventilation of the room at night should constantly be kept before the mother.

No form of infant care is more valuable than that carried on at a well-conducted infant welfare centre. This work has only been in existence since 1910, and the results attained must not be measured by the reduction of child mortality during that short period. The prevention of deviations from the normal, with the consequent disease which such departures entail, is at least as important as mere reduction of the death rate, if the quality of the race is to be materially improved.

A disease such as scurvy can be prevented by comparatively simple means, and, as a matter of fact, has now been well nigh abolished, except in a small number of infants who are kept rigidly to certain varieties of patent food deficient in anti-scorbutic properties.

No such sensational arrest of rickets is possible while the conditions of overcrowding in large towns persist. But the action of the community, if well informed in matters of hygiene, can do much to ameliorate these conditions. No factor is of greater importance than the education of the motherhood of the nation, and it is in this field that the greatest advance has been made within the last few years.

By the time the child has reached school age and has come under the supervision of the school medical officer the nature of the work has changed and the measures to be employed are largely remedial. Defects following on the rachitic state have now established themselves, notably enlargement of the tonsils and adenoids, suppurative otitis media, carious and defective teeth, and stunted growth associated with muscular weakness, lax ligaments, and anæmia and debility.

Many of the children of the poor and of the slum dweller when they are first sent to school are already struggling through the rachitic phase of their existence, and much can now be done to help them on their way to recovery.

The site of the school should be as open and airy as possible. Such spaces are, however, not easily obtainable in the areas where they are most required, and the result is that

too often schools are situated in mean streets and are closely surrounded on all sides by dwellings or are overlooked by factories and warehouses. In the older type of Council schools the staircases, passages and classrooms are gloomy, cold, and depressing, while the playgrounds lack space and are often damp and cheerless. Every effort should be made to make both school and playground as light and as airy as possible. Bright tiles, light walls and coloured pictures do much to relieve the dull monotony of these buildings, and need not add materially to the expense. It must be remembered, that in school there is the one opportunity of introducing into the lives of these children, for five or six hours daily, a wholesome environment of which their life is otherwise entirely deprived.

The open-air method of education has been employed by the London County Council for some years, and even on the very limited scale on which it has been introduced has proved of great advantage to the children. Besides open-air day schools, classes are held in the playgrounds, or better still, in public parks and open spaces, while country holidays and school camps introduce a very necessary change into the dull monotony of their lives.

The development of physical education is very necessary if the best results are to be obtained among these children whose opportunities of wholesome exercise are so extremely limited. The defective rickety child lacks initiative and requires to be taught how to play. Organised games no less than carefully graduated gymnastics are of the greatest benefit to its mental and physical development.

Much attention has been paid to the harmful influence of active service conditions and the effect of overstrain, both physical and mental, on the constitution of the recruit in the late war. There is fortunately another side. In the majority of the younger recruits, the benefits accruing to training and life in the open, combined with an ample supply of good food, produced most beneficial effects on the growing youth, who had formerly dwelt in a crowded city, and had been confined all day in an office or warehouse.

While there is much to be said against a conscript army, there is little to be said against conscripting the youth of the nation for health purposes. Every encouragement should be given to the numerous organisations which exist for promoting outdoor and camp life under discipline for young children. This movement might well be extended on a national scale.

It is along these slow and laborious lines that the prevention and the amelioration of the disease are to be looked for, and not by the successful combating of any supposed or actual intestinal toxæmia, or by the addition of a missing food factor to the diet.

Food in Rickets.—The statement has already been made that there is no known food which will protect the infant from rickets if the environment is favourable to its production. Even an ample supply of breast milk from a healthy mother fails to give protection. This has been noted among the Jewish mothers in the East End of London. It is true also of Italian children in London. Dr. Grulee, of Chicago,* states that in an examination which he made of five hundred negro babies in that city between the ages of six months and eighteen months, all—without exception—exhibited rachitic symptoms and bone changes, although many showed no gastro-intestinal symptoms and were fed carefully on the breast.

Hess, of New York, has also recently come to the conclusion that rickets arises in cases when the food supply is adequate and the fats are abundant.

But while this is true, it must be remembered that rickets, like many other morbid processes not necessarily associated with deficient or defective feeding, is a disease of malnutrition and that the food supply is a matter of great importance in treating the disease. It is a disease of malnutrition in the large sense in which Jenner used the term, namely, that there is a faulty metabolism of the tissues which leads to the production of unhealthy structure in the place of healthy.

* "Infant Feeding," by Clifford G. Grulee, Philadelphia and London, 1912.

The conditions which produce rickets occur most commonly among the lower class and the poorer portion of the community, and for this reason they are frequently associated with errors in diet. But too much has been made of the imputed absence of breast feeding. The poor more than the wealthier portions of the community are zealous in trying to suckle their children. It is more commonly the mothers of the well-to-do classes who are half-hearted in their efforts and who are apt to give up the attempt at the first difficulty which arises. There is no question that an adequate supply of milk from a healthy mother is one of the greatest safeguards of the health of the child. The mother's milk is that which is best adapted to the infant's digestion, and the risk of infection, notably of intestinal infection, is markedly diminished.

This is due to several causes, for not only is the child supplied with a food perfectly adapted to its digestion at the various stages, but it is supplied with a fluid which is sterile, and which confers a large share of the immunity which the mother herself enjoys. The notable freedom of breast-fed infants from all forms of infection has long been a matter of common knowledge and of general experience. There can be but little doubt that the conditions of modern civilisation generally have a harmful effect on the expectant mother, not only increasing the risks attendant on labour, but also diminishing the prospect of a normal and healthy period of lactation. In a certain number of mothers, say about 10 per cent., it is advisable to recognise that they are incapable of nursing the child, and to place the infant at an early date on artificial feeding.

When this is necessary, cow's milk is the best substitute. Comparatively few children are unable to digest cow's milk, but unfortunately there is one great drawback to its use, and that is that it forms a most excellent culture medium for the growth of bacteria. Attention to the purity and cleanliness of the milk supply are matters demanding urgent attention in this country. Milk of a certified grade, guaranteed to come from tuberculin tested cows, and to be of a

certain standard of cleanliness can be procured, but it is not always easy to obtain, and is sold at a price which is prohibitive to the poor. So-called nursery milk is by no means reliable and frequently differs from ordinary milk only in the fact that it is sold in bottles.

When the quality of the milk is in question and when the facilities for storing it are wanting, as they usually are in slum areas, scalding the milk is a wise precaution. In scalding, the milk is simply brought to the boiling point, and is then immediately taken off the fire. The use of dried milk is most useful in these cases, and experience with its use in baby centres throughout the country has been most favourable. The milk is sterile and can be prepared in small quantities as required, matters of great consequence in the dwellings of the poor, and especially important in a disease such as rickets, where the child is already prone to catarrhal infections.

The evaporation of the milk in the process of preparation does not seem to destroy its nutritive value. Dr. C. K. Millard, Medical Officer of Health for Leicester, one of the pioneers in recommending the use of dried milk, informs me that in that city over £10,000 worth of dried milk was sold during the year 1920, and that the results as regards the health and nutrition of the infant were most satisfactory.

When milk of good quality can be procured there is an advantage in the use of the natural product, but when the cleanliness is doubtful or storage room is deficient, especially during the summer months, the use of dried milk is to be recommended. Milk after desiccation seems to be more digestible than ordinary cow's milk, but if there is difficulty in digesting the full-cream variety, half-cream dried milk may be used as a temporary expedient. When the child is incapable of digesting cow's milk, the use of ordinary sweetened condensed milk is often useful as a temporary expedient, but its use should not be continued.

Fat, especially in the form of cod-liver oil, has long been considered useful in the treatment of rickets, and has by

many been considered a specific. There is no doubt of its utility in properly selected cases. So firmly has the belief been established for many years, that practically every child who does not thrive, no matter to what class it belongs, is placed straight away on one of the many forms of cod-liver oil, either plain or combined with malt.

For some years, malt and cod-liver oil have been used fairly freely in certain of the London County Council schools with very varying results. As already noted, in children who are badly nourished the most serious deficiency is in the proteid element of the diet. It is of little utility to supply cod-liver oil to a child whose food supply is deficient all round in the elements which go to constitute a healthy dietary. My own experience has been that these children benefit much more from the supply of a certain quantity of milk daily, even if that be only half a pint, which is the quantity usually supplied.

In baby centres the general experience with fats has been that most of the varieties of fat produced the same favourable result, and the question arose how far the action of the fat was a mechanical action on an irritated intestinal mucosa. Clinically, the vegetable fats seemed to produce equally favourable results with the animal fats.

One matter is of great importance, and that is that to get the best results the fat should be in the form of a perfect emulsion. Ordinary emulsification by hand with the use of tragacanth is not nearly so efficacious as the very perfect emulsification produced by mechanical means. The success of many of the patent emulsions is probably due to the very perfect sub-division of the fat globules, which remain distinct and do not tend to run together. Emulsions of petroleum have practically no direct nutritive value, but have been found of great value from their local lubricant action, combined probably with a certain inhibitory influence on bacterial activity.

Clinically, bacon fat has been found one of the most efficient modes of administering fats in an easily digestible form to infants, and it is impossible to agree with laboratory

experiments which seem to suggest that it is of little or no nutritive value.

Yolk of egg is a useful addition to the diet of the healthy child and is most beneficial in rickets. From the sixth month the infant may be given a few spoonfuls of the yolk of a lightly boiled egg. Up to the age of two years, the child should take two pints of milk within the twenty-four hours, and the morning and evening meals should consist principally of milk with bread and butter.

From the age of ten to eighteen months, a cup of good beef-tea should be given to the child for its mid-day meal, at first every other day but later each day. A little stale bread or rusk may be given with the beef-tea or a mealy potato well mashed with a spoon.

The preparation of good beef-tea is not always easy to carry out, and a reliable meat extract is often a useful way of preparing a cup of beef-tea for the mid-day meal. These meat extracts are often fortified by the addition of meat fibre and albumen, but cannot, even then, be regarded as efficient foods in themselves, for the quantity of proteids present is but small. Nevertheless, beef-tea and meat extracts undoubtedly lead to a better digestion and absorption of the ordinary diet, so that they have both a direct and an indirect nutritive value.

In the debilitated states of rickets, raw meat juice and raw meat pulp are valuable adjuncts and act as stimulants, easily digested and absorbed, especially when there is any intestinal complication.

Meat may with advantage be given to the child from the eighteenth month onwards in the form of a little finely shredded or carefully pounded roast mutton. If meat be excluded from the diet of the child, the best results as regards growth are not obtained. The child can quite well digest meat; and indeed, in chronic diarrhoea and intractable catarrhal affections of the bowels, it is a very valuable form of treatment to cut off for a little all forms of milk food and to keep the infant on raw meat juice, raw meat pulp, and albumen water.

While the adult may with advantage cut down meat to a very small proportion when there is a failure of elimination, the young organism is dependent on a relatively large proteid supply if efficient growth and development are to be maintained.

Poverty and want of food are not by any means the most common causes of under-feeding in children. In slum areas and among rachitic children deficiency of the proteid and fat elements is the commonest error. The child is given portions of what the rest of the family eat, and if a child be allowed other foods it readily loses the desire for milk, and can only be made to take it with difficulty. The need for supplying the proteid deficiency has been emphasised, for in most works on rickets the administration of a suitable fat is usually spoken of as if it were the one specific method of treatment.

During the first year the infant thrives on milk and milk foods, and it is a common error to continue this diet without change during the second year. The child fed on a milk diet entirely has not the energy nor the power of resisting disease possessed by the child who receives a more varied diet.

I have not been impressed by excess of carbohydrates in the food as a common cause of error in the infant's metabolism, where the other dietetic elements were supplied in sufficient quantity. All over the East the early addition of starchy pap food to the diet is exceedingly common, but rickets never results.

Variety is to be aimed at, but that must be tempered with moderation during the first two years. The pulp of a well-baked apple beaten up with sugar and cream, scraped banana, the inside of a grape from which the pips and skins have been removed, or one or two teaspoonfuls of orange juice are all useful about eighteen months, but indigestible fruits and raw apples should be avoided in young children. At the third or fourth year, a raw apple may be allowed, provided it is not eaten at the evening meal and is used with caution in warm weather. The fibre of the apple, it is true, is useful in cleansing the teeth, but it must be remembered that by

the third or fourth year the main part of the enamel of the permanent teeth has already been laid down and the main failures in the defence of the teeth have taken place long before this period. In other words, no fruit diet can at this late period be expected to have any action whatever on the actual structure or formation of the teeth. By the third or fourth year of life the teeth of the permanent set are well nigh completed.

CHAPTER XXX

The Treatment of Rickets (*continued*)

IN the last chapter, some of the general principles applicable to the treatment of rickets were enunciated. A few words may, with advantage, be said as to their application to the individual.

If a rachitic child does not make satisfactory progress and it is difficult to find a suitable food, nothing is likely to be more effective than a change of air either to the country or to the seaside. Sea air, if the exposure be not too rigorous, seems to be especially beneficial, and not infrequently without any alteration in the diet or of the usual regimen, beyond the change of air, the child begins to thrive at once. In England, the more bracing climates on the east coast are to be preferred, such as Margate, Folkestone, Broadstairs, Lowestoft, and Scarborough. A short change to such a climate often proves the turning point to the rachitic child, and infants who have been making no progress for months and who have been placed on one food after another in the vain effort to find some food which they could digest, progress and put on weight immediately, and the food previously rejected is easily retained and assimilated. In the case of the poor, unfortunately, such a change is not easily arranged, but much excellent work has already been done by voluntary agencies, who lay themselves out to secure the necessary change for the child of the slum dweller.

The difficulty of feeding the infant has been greatly exaggerated, and defective growth is often attributed to failure of the digestive powers, when the nature of the error

lies in a vicious environment which interferes with the healthy action of every organ in the body.

Scrupulous cleanliness is of the greatest importance to the rachitic child. It has already been stated that Kasso-witz believed that ammoniacal decomposition of the urine, where cleanliness was not observed, vitiated the atmosphere which surrounded the infant and led to the development of rickets. While it is unlikely that the breathing of these ammoniacal vapours is in itself a cause of rickets, it cannot be doubted that careful cleansing of the skin is of the greatest value in the prevention of rickets. The child should have a warm bath in the morning, and the whole body of the child should be carefully sponged each evening. The training of the infant from the first to habits of cleanliness and the frequent changing of soiled clothing are of the first importance in the rearing of a healthy child. The stimulation of the skin by means of baths has a most beneficial effect on the general metabolism of the infant. Cold douches are exceedingly useful, due care being taken to avoid shock. In warm weather the child may be seated in a tepid bath while colder water is squeezed over the shoulders. The use of salt water and of sea water affusions are simple remedies which ought to be much more freely used than they are. They have a most wholesome effect in toning up the system in the debility of rickets.

Medicinal Treatment.—The scope for the medicinal treatment of rickets is comparatively limited.

The administration of cod-liver oil has already been dealt with, as this is more a food than a drug. As a rule, the tendency is to give the oil in too large doses. For an infant, it is well to begin with small doses of ten drops three times a day. The combination with malt is a pleasant and useful method of exhibiting the oil, especially if the plain oil is not well tolerated. Emulsions are frequently more easily retained and are better assimilated.

In Europe, phosphorus has been much lauded as a specific in the treatment of rickets. It is usually given in doses of one two-hundredth part of a grain and should be given after

food. Cod-liver oil is the commonest vehicle used in its administration. The following are convenient formulæ for its administration :—

1. Phosphorus 1 grain.
 Absolute alcohol 350 minims.
 Spirit of peppermint 10 „
 Glycerine—up to 2 ounces.
 Six to twelve drops three times a day after food.
2. Phosphorus $\frac{1}{8}$ grain.
 Almond oil 1 ounce.
 Gum acacia 4 drachms.
 White sugar 4 „
 Distilled water 1½ ounces.
 One to two teaspoonfuls three times a day after food.
3. Phosphorus $\frac{1}{7}$ grain.
 Cod-liver oil 3 ounces.
 One teaspoonful three times a day after food.

It has been suggested that deficiency of phosphorus may be a cause of rickets. This is unlikely, for the disease frequently develops in children who are taking a sufficiency of cow's milk, which, as Bunge points out, contains six times as much of this element as human milk. Nor can it be reasonably maintained that the administration of this exceedingly small dose of phosphorus is sufficient to lead to the normal laying down and combination of the calcium in the various centres of ossification.

Its value has been chiefly insisted on by Kassowitz, of Vienna, and by Jacobi, in New York. Its use has found but little favour in this country, and the probability is that the usual vehicle in which it is given—cod-liver oil—is more efficacious than the drug itself.

Iron is often of utility, especially in older children. The vinum ferri may be given in doses of from twenty to forty minims. The compound syrup of the phosphate of iron in doses of from half to one teaspoonful is also a convenient preparation which is well tolerated. It is especially useful in the pale, flabby, often unduly fat and lymphatic type.

When the digestion is at fault a small dose of grey powder

is often efficacious, and in young infants the administration of from a quarter to a half grain for three to six successive nights may be employed with advantage. When the motions are pale and pasty and are accompanied by mucus, the use of a small dose of calomel is often helpful. A useful combination is :—

Hydrargyri cum creta	...	...	gr. $\frac{1}{4}$
Hydrargyri sub-chloridi	...	...	gr. $\frac{1}{8}$
Sacchari lactis	...	...	gr. iii

When there is much mucus in the stools, the use of small doses of castor oil are very useful, and it may be employed with advantage in the beginning of the treatment of diarrhoea whether acute or chronic.

When the tongue is furred white or yellow, and the motions are green and slimy, the following simple mixture is of service :—

Olei ricini	...	...	...	...	℥i
Mucilaginis acaciæ	...	...	...	...	āā ℥iii
Syrupi	...	...	...	...	
Aquæ ad	...	...	...	...	℥iii
Misce.	℥ii ter in die.				

When there are signs of nervous irritability such as night terrors, laryngismus stridulus and the irritation associated with teething, I have been impressed with the value of phenacetin in quite small doses. It may be usefully combined with griseofulva powder as follows :—

Hydrargyri cum creta	...	gr. $\frac{1}{8}$ — gr. $\frac{1}{2}$
Phenacetin	...	gr. $\frac{1}{4}$ — gr. i
Sacchari lactis	...	gr. iii
Fiat pulv.		

When the nervous symptoms do not answer to simpler treatment, bromides may be given in doses of one or two grains every two or three hours in the case of an infant a month or two old. When convulsions occur, the use of bromides is indicated after administering a preliminary dose of castor oil. The bromides should be continued for some days after the convulsion and should be given three times daily in diminishing doses. Chloral hydrate is useful in

some of the severer cases of convulsion, and may be given in one to five-grain doses combined with bromides, preferably by rectal injection. The use of the hot bath in convulsive seizures is usually recommended and is very effectual during the actual convulsion. The temperature commonly recommended—104° or 105° F.—is too high, a temperature of 95° or 96° F. being, as a rule, sufficient. While the child is lying in the hot bath, cold affusion should be applied to the head. If the fit be severe, the administration of chloroform is exceedingly useful and may be proceeded with at once without waiting for the hot bath. Small doses produce a rapid result and, with the young child, can be repeated with safety if required.

In laryngismus stridulus a similar line of treatment should be followed. Placing the child in a hot bath and sponging the chest, back and front, with cold water twice a day is a useful form of treatment in these cases.

In rickets, massage of the whole body is a most valuable adjunct to the treatment. This may be employed with the hand alone after the bath. The friction promotes the action of the skin, improves the circulation and tones up the whole muscular system. It has a marked soothing effect on the nervous system.

When there is difficulty in getting the child to assimilate cod-liver oil by the mouth, it may very conveniently be introduced into the system by friction. It is, however, an unpleasant application, and friction with any simple animal fat, olive oil, neat's-foot oil, or benzoated lard, is free from this unpleasantness and seems to be equally efficacious. These oil frictions act in three ways, viz. :—

- (1) by introducing fats into the system ;
- (2) by soothing the irritable nervous system ;
- (3) by increasing the quantity of all the secretions ; the urine becomes more abundant and the function of the liver is promoted.

The persistent use of massage after the child's bath is a most useful form of treatment in all cases of rickets, except in the severer cases where the limbs are too tender to be manipu-

lated. Through the cutaneous surface, both by means of graduated baths and frictions, a most powerful tonic effect can be produced on the whole system, which is of the greatest value. The rubbing should be continued for from four to six weeks and should be carried out on a systematic plan. It is well to begin with the lower extremities, and at first the friction should be gentle, especially if there is tenderness. At first, manipulation is painful, but after a time firmer pressure can be made, working from below upwards. Passive movement of the ankle, knee and hip is also useful. From the lower limbs the mother should pass to the abdomen, thorax, neck and upper extremities. The whole manipulation should last about ten minutes, and can be quite well carried out by the mother if the various movements, which need not be of a complex nature, are explained to her.

Surgical Treatment of Rickets.—When a child with deformities of the long bones is brought for consultation, the mother is usually reassured and told that in time these will pass away. Now, this is true in many cases, especially if measures are taken to remedy the conditions which have produced the disease.

But it must always be borne in mind that in all large cities in England, and still more on the Continent, notably Vienna, Buda-Pesth, Berlin and Paris, large numbers of cases present themselves with curvatures of the long bones which require surgical interference. Before the war the chief work of the orthopædic surgeon lay in the correction of rachitic deformities.

Indeed, contrary to what is usually supposed, bony changes occurring in this disease are remarkably persistent and, in many cases, may be observed in advanced life if they are carefully looked for. The bending of the long bones tends to disappear in the majority of cases, it is true. But the changes in the skull such as the thickening of the frontal bones or of the parietal bones are often exceedingly persistent and remain throughout life. Deformations of the thorax due to rickets, not necessarily pigeon breast, are very common in the adult. Lateral deviations of the spine, flat foot and knock-knee supervene at a later period and do not always

tend towards spontaneous cure. Most important of all, the bony changes in the pelvis in women are apt to be very persistent, and are likely to lead to dystocia, and to increase the dangers of labour to both mother and child. Most of the severe deformities demanding Cæsarean section are, as has been seen, due to rickets.

Tibial curves are probably the most frequent deformities which have to be dealt with surgically. It must be remembered that, while rickets is responsible for the softening of the bones and the relaxation of the muscles and ligaments which support the joints, the actual bending of the bone is due to mechanical causes, and means must therefore be taken to obviate them. Often these children with a framework defective in rigidity and resiliency, are solid, fat, and heavy, and it can readily be understood that if they are allowed to stand a great deal at an early date, bowing of the tibia is very likely to occur.

A large amount of judgment is required as to the line of treatment to be adopted. Obviously, it is desirable to keep the weight off the limbs, but it is still more important that the child should have ample opportunities of exercise. In the ordinary outward bowing of the tibia, this can usually be attained by giving daily baths, accompanied by massage and passive movements of the limbs three times a day, while splints are employed in the intervals between the exercises. If the child is under three years of age, and the outward curve of the tibia is not very marked, a splint should be applied to the inner side of the limb, extending from two or three inches below the perinæum to two or three inches below the ankle. Straps at the top and bottom retain the limb in position, while a third band at the point of greatest convexity produces a continuous pressure which tends to straighten the limb. The projection of the splint beyond the ankle prevents the child getting on its feet.

At first the splint should be worn continuously night and day, but as the condition improves, the child may be allowed the gradual use of the limbs, the splints being used after a time only at nights. As soon as possible, splints should be

discarded. If the child is over three years of age, the same treatment should be given a fair trial for some months. Similarly with anterior curves of the tibia, splints should be given a fair trial.

If these measures are not successful, recourse must be had to osteotomy. The operation is a simple one. An osteotomy knife is passed on the flat through the skin over the crest of the tibia and over the inner surface of the bone at the most prominent part of the curve. The knife is then turned at right angles so as to divide the periosteum. Along the knife the blade of a fine Adams' saw is introduced, and as the knife is withdrawn, the skin incision is enlarged to prevent the heel of the saw abrading it. About two-thirds of the thickness of the tibia is now sawn through, and the fracture of the remaining third and of the fibula is completed by manipulation. In more severe cases, removal of a wedge of bone may be required before the deformity can be corrected. Some surgeons still employ the older method of osteoclasis, or fracture of the bone at the point of greatest curvature, over a wedge-shaped block by means of manipulation. In this way a green stick fracture is produced, a wedge-shaped gap appearing at the hollow curve of the bone. In all these cases the limb must be secured in the straight position by means of plaster of Paris bandages, or by back and side splints.

Knock-knee, as has been shown, may occur in the very young child associated with active signs of rickets, or it may occur from twelve to eighteen years of age, when it is known as the static variety. It is only static in the sense that it is due to the operation of mechanical forces on a limb in which the bones, muscles and ligaments are all weakened as the result of an attack of rickets only partially recovered from. Deformities occur at adolescence as the result of a disproportion between the weight and the rigidity of the column supporting it. This disproportion may arise in two ways :—

- (1) by undue increase of the weight, as when a growing child carries heavy weights over a prolonged period. In such a case even a healthy bone would give ;
- (2) by weakening of the support, which is much the more

common cause of the disproportion. In nearly all these cases belonging to the second class, the weakening of the supporting column is the result of rickets in early life. The rachitic process itself, in the great majority of cases, has not recrudesced, for the conditions which produce it are not commonly present at adolescence, but the weakness of the bones has existed ever since the early attack, and has now become manifest as the result of the added strain.

Quite a large number of cases of knock-knee recover without treatment, but this cannot be guaranteed in any individual case. In the young child when the condition is slight, the recumbent posture, massage, open air, and daily manipulation of the limb, employing pressure so as to correct the deformity, will suffice to effect a cure in many cases. The attitude and walk of the child in all these deformities is important. In the tired subject, as previously noted, the weight is taken off the muscles and the strain is thrown on the ligaments, notably the internal lateral ligament of the knee which is stretched and weakened, while the weight falls on the inner border of the foot and the arch sinks. The child tends to separate the feet in walking so as to increase the base of support and points the toes markedly outwards. There is no resiliency in the step. It is important to correct this habit and to teach the child to walk with slightly in-turned or parallel feet.

In more severe cases Sir Robert Jones recommends the Thomas' Knock-knee Brace, which is a bar of iron running into the heel of the boot, placed to the outer side of the limb and reaching as high as the great trochanter. A posterior bar reaches well above and below the knee. The knee is first bandaged to the posterior bar to keep it fully extended, and afterwards to the lateral bar to correct the lateral deviation. During the night, shorter splints should keep up the improved position ; later, the day splints can be discarded and only the night splints used. Jones makes two important observations as to the mechanical treatment of knock-knee. Firstly, all jointed splints for the correction of knock-knee are quite useless, as the pressure strain of the splint is rapidly

lost during the act of flexion. Secondly, the test of recovery and the sign that the splint may be discarded is when the straightened knee fails to yield laterally on manipulation.

Any case of knock-knee may be cured in this way, but naturally, when the condition occurs in later life, the long period of treatment required militates against its use, and usually some form of operative measure is required.

Some surgeons still employ forcible straightening of the knee by manipulation or by means of the osteoclast. The degree of violence required to produce a fracture is often very great, and osteotomy is to be preferred. Linear osteotomy of the lower end of the femur just above the epiphyseal line, according to McEwen's method, is a safe operation, and is very successful in its results. It has largely replaced Ogston's operation, which had the serious objection that it opened the knee joint while the internal condyle was obliquely sawn through.

The treatment of flat foot is a problem which is very commonly placed before the practitioner. Teaching the child to walk with the toes pointed directly forwards so that the inner borders of the feet are parallel is an important part of the prophylaxis of flat foot. It is not expedient in the young child or the young adolescent to insist straight away on severe tip-toe exercises and movements which simply throw an extra strain on muscles already overtaxed. Attention to general hygiene, change to a sea climate, salt water foot baths and douches, combined with massage and movement of the foot and ankle, are important preliminary measures. At the same time, adequate periods for rest should be insisted on. Many cases will be arrested and many will be cured by attention to these measures alone. Carefully regulated exercises may now be usefully employed, tip-toe exercises for two or three minutes twice a day being sufficient at first. The duration and the number of the exercises may be gradually increased as the muscles regain strength. Placing the feet close together and inverting the soles so that the body weight rests on the outer border of the foot is also a useful exercise.

The supply of a support to the arch of the foot in the form of a valgus plate is frequently of value. It is sometimes stated that these are harmful in that they take the work from the muscles and ligaments and throw it on to an artificial arch. But a well-made steel or aluminium brace, light and comfortable to the foot, does not interfere with its movements. It should be resilient as well as light so that there is a fair amount of give and spring, combined with a continuous support to the arch which allows it to retain its shape.

When the flat foot has advanced further so that the bones become fixed in position and the tendons of the peronei muscles and the ligaments are contracted, forcible rectification of the foot under an anæsthetic is likely to be required. This method of treatment is safe and effective. This *redressement forcée* is carried out, under an anæsthetic, over a wedge-shaped block, and the foot should be over-corrected as far as possible while plaster bandages are applied so as to retain the foot in the adducted and inverted and slightly flexed position. The plaster should be allowed to dry before the patient comes out of the anæsthetic, and the bandages should be retained in position for one month. This method of treatment is safe and effective, but it may require to be repeated to obtain a good result. Very occasionally in old and intractable cases operative measures, such as resection of the astragalo-scapoid joint according to Ogston's method, or excision of a wedge from the head and neck of the astragalus (Stokes' operation), may be required.

The spine should be carefully observed in rickets. Kyphosis or posterior projection of the spine is not uncommon in young infants as the result of muscular debility. Such infants should be kept lying on a padded wicker tray which can be easily carried about, and the child should be nursed as far as possible in the reclining position. The general treatment of the disease is most important in these cases, and bathing and massage of the spinal muscles should be employed. If the child is able to sit up, a back splint of leather or of malleable iron covered with leather, with axillary and

perineal straps, may be usefully employed to keep the back straight. Breathing exercises are very essential, especially if pigeon breast is an associated deformity. Round shoulders is an exceedingly common form of kyphosis in rickets, and should be treated by strengthening the enfeebled muscles in the ways already indicated, and by correcting the deformity by means of suitable exercises.

Scoliosis or lateral curvature of the spine is a condition common in rickets from a very early period. It requires the greatest care both as regards diagnosis and treatment. The essence of scoliosis is that there is a rotation of the vertebræ around a vertical axis, and though this is usually associated with bending of the spine to one or other side, the lateral deviation is by no means a necessary concomitant.

In weakly and delicate children, or after an acute illness, there may be a simple lateral deviation of the spine without rotation. Provided there is no structural change in the bones, lateral deviation of the spine is very amenable to treatment. The correction of faulty attitudes and the strengthening of the muscles by appropriate exercises are of the greatest importance.

The true form of scoliosis in rickets has gone a stage further. It is due to a faulty position which has become stabilised and has led to the rotation of the vertebræ with osseous changes which do not admit of cure.

The question of retentive supports in scoliosis has been very hotly contested. Where actual structural alterations have occurred and a cure cannot be hoped for, the use of a light form of spinal jacket is clearly indicated to prevent the deformity becoming worse. A divided plaster jacket, capable of being easily removed for the purposes of exercise and education in proper breathing, is often very essential. It is very necessary to recognise the cases requiring a spinal support, for a policy of simply letting the patient drift will almost certainly tend to an aggravated condition, incapable of cure, and beyond the hope of amelioration by suitable exercises.

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